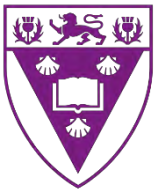
# A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change

Submitted in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY IN INFORMATION SYSTEMS

(FACULTY OF COMMERCE)



RHODES UNIVERSITY

by

**Callie Thomson**

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# Abstract

The global pandemic of noncommunicable diseases and its associated premature mortality rates and socioeconomic burden have led to increasingly intensified efforts towards designing and delivering health promotion interventions aimed at addressing the leading modifiable health risk behaviours, such as physical inactivity. Developing physical activity behaviour change interventions that target individuals at the dual intra-interpersonal socioecological levels of health promotion has become a key objective worldwide. Digital and mobile technology is revolutionising the ways in which health behaviour change interventions are delivered to individuals across the world, with mobile health applications (mHealth apps) increasingly recognised as a powerful means of promoting physical activity behaviour change. However, with the growth and opportunities of mHealth apps, come several design challenges. Key design challenges concern the integration of theory, the incorporation of evidence-based behaviour change techniques, the application of persuasive systems design principles, and the importance of multi- and interdisciplinary collaborative design, development and evaluation approaches. These key challenges influence the output product design and effectiveness of mHealth physical activity behaviour change intervention apps.

There exists a paucity of approaches for guiding and supporting the multi- and interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps. To address this gap, this research study proposes an Interdisciplinary mHealth App Design Framework, framed by a novel boundary object view. This view considers the diverse communities of practice, boundary objects and supporting artefacts, process activities, and knowledge sharing practices necessary and relevant to the design of effective mHealth physical activity behaviour change intervention apps.

The framework's development is guided by a Design Science Research (DSR) approach. Its core components are based on the findings of a critical theoretical analysis of twenty existing multi- and interdisciplinary digital health development approaches. Once developed, the framework is evaluated using a qualitative DSR linguistic interpretivist approach, with semi-structured interviews as the research instrument. The thematic analysis findings from interviews with thirty-one international academic researchers and industry practitioners informs the iterative modification and revision of an enhanced Interdisciplinary mHealth App Design Framework, constituting the main DSR artefact contribution of the research study. In addition, four theoretical contributions are made to the mHealth intervention app design body

of knowledge, and a practical contribution is made through the provision of guideline recommendations for academics and industry practitioners. Methodological contributions are also made in terms of applying DSR, adopting a hybrid cognitive reasoning strategy, and employing a qualitative linguistic interpretivist approach to evaluation within a DSR project.

# Declaration

I, Callie Thomson, declare that the thesis, entitled *A Framework for Guiding the Interdisciplinary Design of mHealth Interventions for Physical Activity Behaviour Change*, which I hereby submit for the degree, *Doctor of Philosophy in Information Systems* at Rhodes University, is my own original work. I also declare that this thesis has not been previously submitted by me for a degree at this or any other tertiary institution, and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.



Callie Thomson

*To the brave warriors living with serious mental health disorders,*
*who wake up every day to fight the same battles that left*
*them so exhausted the day before.*

*To the courageous warriors who have*
*lost their lives to the fight.*



*I know it's hard.*
*Keep fighting.*



*If you hear a voice within you say*

*"You cannot paint"*

*Then by all means paint*

*And that voice will be silenced.*

*– Vincent van Gogh –*



*Don't be afraid it won't be perfect.*
*The only thing to be afraid of, really,*
*is that it won't be.*

*– Company, Stephen Sondheim (1970) –*



## *Everybody Says Don't*

*– Anyone Can Whistle, Stephen Sondheim (1964) –*



*Everybody says don't*
*Everybody says don't*
*Everybody says don't, it isn't right*
*Don't, it isn't nice*

*Everybody says don't*
*Everybody says don't*
*Everybody says don't walk on the grass*
*Don't disturb the peace*
*Don't skate on the ice*

*Well, I say do!*
*I say walk on the grass*
*It was meant to feel*
*I say sail*
*Tilt at the windmill*
*And if you fail, you fail*

*Everybody says don't*
*Everybody says don't*
*Everybody says don't get out of line*
*When they say that*
*Then, lady, that's a sign*
*Nine times out of ten*
*Lady, you are doing just fine*

*Make just a ripple*
*Come on, be brave*
*This time a ripple*
*Next time a wave*

*Sometimes you have to start small*
*Climbing the tiniest wall*
*Maybe you're going to fall*
*But it's better than not starting at all*

*Everybody says no*
*Everybody says stop*
*Everybody says musn't rock the boat*
*Musn't touch a thing*
*Everybody says don't*
*Everybody says wait*
*Everybody says can't fight City Hall*
*Can't upset the cart*
*Can't laugh at the King*

*Well, I say try!*
*I say laugh at the kings*
*Or they'll make you cry*
*Loose your poise*
*Fall if you have to*
*But, lady, make a noise!*

*Everybody says don't*
*Everybody says can't*
*Everybody says wait around for miracles*
*That's the way the world is made*

*I insist on miracles*
*If you do them*
*Miracles*
*Nothing to them*
*I say don't*
*Don't be afraid!*

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*I can no other answer make but thanks,*
*And thanks; and ever thanks…*
*– William Shakespeare –*

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To Professor Ojelanki Ngwenyama, who invited me to go within, for within are where all the answers lie. Your invitation gave me permission to reflect on my then research journey and explore whether I was headed in the right direction. This process of self-reflection shed light on my (old) path, allowing me to see more clearly, and I knew a big change needed to be made. After careful introspection and deliberation, I walked away from my original project, despite being 18 months in, and embarked on a new journey, seeking a new area of specialisation and topic that would be an authentic expression of self. It's now several years later, and I have never once regretted the decision. I am where I am today because of your invitation, and will forever be deeply grateful for the profound impact you've had on my life. Thank you.

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# Chapter 1

## Introduction

*When you're doing a play and you're afraid of a scene, that's the scene you should embrace, because it's the scene that will tell you something about the play [and] something about yourself.*

*– Raúl Esparza (2006) –*



## 1.1 Introduction

Digital mobile and application (app) technology provides a powerful and increasingly popular means of delivering health promotion behaviour change interventions to individuals across the globe, in efforts to motivate and empower people towards leading healthier lifestyles, and in fighting and reducing the worldwide prevalence of noncommunicable diseases (NCDs) (Knittle, et al., 2016; Faiola and Holden, 2017; Lee, et al., 2018a; WHO, 2019; De Cocker, 2020; Blagden, et al., 2021; Chatterjee, et al., 2021; Sucala, 2021). There are, however, several key challenges associated with the design of mobile health (mHealth) intervention apps, such as those targeting physical activity behaviour change, which influence the effectiveness of said apps, presenting a complex and multidimensional real world design problem (Bondaronek, et al., 2018; Blandford, 2019a; 2019b; Bul, et al., 2020; Salwen-Deremer, et al., 2020; Schroé, et al., 2020; Chatterjee, et al., 2021).

At the root and heart of this design problem there exists a paucity of multi- and interdisciplinary approaches to guide and support the synergistic amalgamation and integration of heterogeneous knowledge, expertise, skills and practices from multiple relevant disciplines, including health science, psychology, information systems, computer science, and business (Murray, et al., 2016; Perski, et al., 2017; Blandford, et al., 2018; Kowatsch, et al., 2019; Taj, Klein and van Halteren, 2019; van Gemert-Pijnen, et al., 2018; Walsh and Groarke, 2019; Bendtsen, et al., 2020; Hermsen, et al, 2020; Sellak and Grobler, 2020). A boundary object view provides a novel and valuable perspective to addressing the paucity of approaches. This view emphasises the use and creation of boundary objects and supporting artefacts in guiding and supporting interdisciplinary project teams in carrying out heteropraxial activities and knowledge sharing practices during the process of collaboratively designing, developing and evaluating mHealth (physical activity) behaviour change intervention apps. This object and knowledge orientated approach can support interdisciplinary collaborating teams through the process of producing more innovative and effective product design solutions that can help motivate and empower more people towards leading healthier lifestyles.

This chapter introduces the research study. The research context and rationale first provide the contextual background of the problem that this study aims to address, followed by the goals of the research. The research methodology employed to conduct this study is then outlined, after which the scope and significance of the research are described. The summary results of the study are then presented, and the chapter concludes with an outline of the thesis organisation.

## 1.2 Research Context, Rationale and Problem Statement

The global pandemic of noncommunicable diseases (NCDs), and its associated premature mortality rates and socioeconomic burden on countries worldwide, has led to increasingly intensified efforts towards designing and delivering health promotion interventions (Allen, 2017; Bennett, et al., 2020; Wang and Wang, 2020; WHO, 2020a; 2020b). These interventions are aimed at targeting the leading modifiable health risk behaviours, such as physical inactivity and unhealthy eating (WHO, 2017a; Budreviciute, et al., 2020). Global institutions such as the World Health Organisation (WHO) and United Nations (UN) have, for many years, poured a considerable volume of resources into developing and implementing evidence-based health strategies, policies and interventions to address NCDs. The WHO's *Global Action Plan for the Prevention and Control of NCDs 2013-2020* (WHO, 2013) and the United Nation's (UN) *2030 Agenda for Sustainable Development* (UN, 2015), for example, incorporate road maps of policy options and goals for countries to focus efforts towards promoting modifiable health risk behaviours and reducing the prevalence of NCDs. Given the significant role the four leading modifiable health risk behaviours play in the permeation of the NCD pandemic, interventions aimed at informing, encouraging and supporting individuals to change their lifestyle behaviours have become instrumental in achieving the WHO's and UN's global health targets.

The health promotion field is core to the development and delivery of interventions intended to encourage, support and empower individuals to take proactive and preventative action towards modifying and changing their health and lifestyle behaviours, reducing their chances of developing NCDs (or a comorbid cluster of NCDs) (De Chavez, et al., 2005; O'Donnell, 2009; WHO, 2009; Charlemagne-Badal, et al., 2015; Robinson, 2021). Given the nuanced complexity of human health behaviour, health promotion interventions are designed using a multidisciplinary range of theories, instruments and techniques that essentially aim to encourage and support individuals in developing and internalising knowledge, skills and abilities for modifying, improving or maintaining their own health and lifestyle behaviours (McLeroy, et al., 1988; WHO, 2009; Conner and Norman, 2017). Broader, large-scale health promotion interventions also aim to create opportunities and improve access to environments and services that affect positive health practices and make healthy lifestyle choices easier for people (Conner and Norman, 2017; De Ridder, et al., 2017). Furthermore, considering that humans are an inherently social species (Bandura, 1998), health promotion behavioural change interventions should be designed in ways that acknowledge and consider the socioecological and interpersonal factors that surround and influence peoples' health and lifestyle behaviours

on a daily basis (McLeroy, et al., 1988; Wingood and DiClemente, 2019). The process of designing effective health promotion interventions is further complicated by the diversity of determinants and correlates that influence human health behaviour change in various geographic, demographic and health behaviour domains/contexts (McLeroy, et al., 1988; McLaren and Hawe, 2005; Golden and Earp, 2012; Punton, 2016; Brug, et al., 2017).

The socioecological model of health promotion presents a theoretically-grounded and evidence-based view that positions individuals at the centre of their surrounding environment. It also describes the reciprocal determinism of interpersonal, organisational, community, societal and supranational factors as determinants and correlates that both influence and are influenced by individuals' behaviours and intrapersonal psyches, knowledge, attitudes, abilities and behaviours (McLeroy, et al., 1988; Dahlgren and Whitehead, 1991; Stokols, 1996; McLaren and Hawe, 2005; Sallis, et al., 2006; Stokols, 2018; Rubinelli and Diviani, 2020). Health behaviour change interventions designed to target two bordering socioecological levels are referred to as dual-level interventions (Golden and Earp, 2012; Stange, 2012).

Focusing on the design of health promotion behaviour change interventions directed at the dual intra-interpersonal socioecological levels allows for a delineated investigation into the role of individuals as core active agents. Agents who are centrally nested within their surrounding environments, and who are able to self-manage and adapt their health behaviour through the harnessing of personalised, educational, motivational and empowering targeted support. Evidence demonstrates that individual, interpersonal and dual intra-interpersonal level health promotion interventions tend to be more effective than multi-level interventions, which often report fewer, inconsistent and inconclusive success (Angus, et al., 2013; Punton, 2016). Arguments have also been made that delivering interventions directly to people have shown to "reach millions of individuals and have an indisputable effect on population health", and that their power to affect large-scale change should not be discounted (Sniehotta, et al., 2017, p.e396). Furthermore, a dual intra-interpersonal focus accounts for individuals inherent need and desire for social interaction and support, which in an increasingly digitised world with social networking and social media platforms, has become ubiquitously embedded in individuals' daily lifestyle patterns and behaviours (Stokols, 2018; Petersen, Prichard and Kemps, 2019; Simeon, et al., 2020).

Focusing on a specific leading modifiable health behaviour, in this case physical activity, further frames and informs the process of designing effective health promotion behaviour

change interventions. This is because the defined targeted health behaviour domain/context, as described above, largely influences which health behavioural change theories, determinants, correlates, mechanisms and behaviour change techniques (and combinations thereof) are selected and incorporated into an intervention's content (Michie, et al., 2013; Choi, et al., 2017; Conner and Norman, 2017; Michie, et al., 2018a; Rhodes, McEwan and Rebar, 2019; Taj, Klein and van Halteren, 2019). These elements are integral to the design and success of effective health promotion behaviour change interventions. Every year, between four and five million deaths could be averted if the global population were more physically active (Strain, et al, 2020; WHO, 2020c; 2020e). The increasing prevalence of physical inactivity across low-, middle- and high-income countries has, within the last decade, repeatedly been described as a worldwide "pandemic" (Kohl, 2012, p.294; Ding, et al., 2016, p.1311; Ding, 2018, p.e1046; Hall, et al., 2021, p.108).

Digital and mobile technology is therefore increasingly being leveraged globally as a powerful and revolutionising mode of delivering health promotion physical activity behaviour change interventions to individuals (Blandford, 2019b; Kickbusch, 2019; WHO, 2019; De Cocker, 2020; Blagden, et al., 2021). Digital and mobile technology has also become high on the agenda for the WHO and many countries' health strategies and intervention plans (WHO, 2011; 2019). In the last ten to twenty years, research into the challenges and opportunities surrounding the digital health landscape and the use of mobile devices and apps for delivering health promotion and physical activity behaviour change interventions has exploded; giving rise to a newly "emerging interdisciplinary field" of study and exploration (Taj, Klein and van Halteren, 2019, p.1; Gao and Lee, 2019; Guo, et al., 2020). Contemporaneous shifts have also been taking place in the transition away from traditional institution-centric health delivery models, towards consumer-centric health delivery models (Demiris, 2012; Edmunds, Hass and Holve, 2019). These shifts parallel the dual intra-interpersonal socioecological approach to health promotion in focusing on encouraging and empowering individuals to actively seek and share health information, engage in autonomous decision-making, and assume self-responsibility in making healthier lifestyle choices and health behavioural modifications (Faiola and Holden, 2017).

The increasing use of mobile devices and apps by individuals to access, track, monitor, store and share their personal health and wellness data (Laxman, Krishnan and Dhillon, 2015) is representative of the growing consumer health informatics subfield and mobile health (mHealth) arena, which both focus on the design, development and evaluation of digital mobile

and app technology tools and interfaces (Demiris, 2012; Flaherty, Hoffman-Goetz and Arocha, 2015; Smith and Keselman, 2021). These emphasise understanding the perspectives, preferences and needs of health consumers as central and empowered individuals managing their own health and wellbeing (Faiola and Holden, 2017). mHealth consumer app technology provides a more cost-effective, accessible, convenient, real-time and efficient means of reaching more people (in comparison to traditional face-to-face settings) (Knittle, et al., 2016), and often capitalises on functionalities such as global positioning system (GPS), third, fourth and fifth generation telecommunications (3G, 4G, 5G), and inbuilt sensors (including the accelerometer and gyroscope) (Kao and Liebovitz, 2017).

Along with the increasing popularity of mHealth (physical activity) behaviour change intervention consumer apps, and growing interests in leveraging their potential and opportunities, come noteworthy challenges and obstacles (Kao and Liebovitz, 2017; Miah, Gammack and Hasan, 2017). The challenges are vast, ranging privacy and security; regulation; networking; data storage, processing and quality; health literacy; accessibility; acceptance and adoption; sustainability; efficacy and effectiveness; theory development; usability; and design (Laxman, Krishnan and Dhillon, 2015; Knittle, et al., 2016; Jusoh, 2017; Lai, et al., 2017; Van Velthoven, et al., 2018; Liew, et al., 2019; NICE, 2020). Over and above are key challenges pertaining to underdeveloped and inappropriate theory and frameworks, poor methodological quality, inadequate guidelines and principles, and a lack of approaches for guiding the design, development and evaluation of mHealth technology (Jusoh, 2017; Kowatsch, et al., 2019; Walsh and Groarke, 2019; Mussener, et al., 2020; Sellak and Grobler, 2020).

These challenges stem from deficiencies in multi- and interdisciplinary collaborations between multiple relevant diverse disciplines, all of which are necessary in contributing to the design, development and evaluation of effective mHealth (physical activity) behaviour change intervention consumer apps (Walsh and Groarke, 2019; Hermsen, et al., 2020). These heterogeneous disciplines include information systems, health science, health psychology, computer science, social science, user experience design, business, marketing, lifestyle-specific domains (such as exercise and sport science), and more (Blandford, 2019a; 2019b; Bendtsen, et al., 2020). Ineffective multi- and interdisciplinary collaborations generally manifest as design related challenges, which significantly influence and impact the effectiveness potential of mHealth (physical activity) intervention consumer apps to motivate, encourage, support and empower sustainable health behaviour change in individuals

(Blandford, 2019b; Kowatsch, et al., 2019; Milne-Ives, et al., 2020). Design, in this research context, is concerned with the conceptualisation and production of mHealth promotion (physical activity) behaviour change intervention apps, as well as activities pertaining to the processual development and evaluation of said apps, which are also viewed through the lens of design.

Approaches to designing mHealth behaviour change intervention consumer apps can be viewed from two broad high-level perspectives, namely a health behavioural sciences perspective, and an information systems perspective. Both sides view design in different ways, are prone to different points of interest, tend to focus on different design challenges, usually propose different solutions and contributions to resolve such challenges, and generally speaking, hold different worldview orientations, knowledge and objectives, and utilise different practices, methods and approaches to mHealth app design, development and evaluation (Blandford, et al., 2018; Blandford, 2019a; 2019b; Bul, et al., 2020). The health behavioural sciences perspective is primarily concerned with: the design, development, implementation and evaluation of the intervention itself (and the basket of intervention components, behaviour change techniques and mechanisms of action that make up the intervention); the application and testing of health behavioural change theory; the evidence-based determinants and correlates of behaviour change; and the measuring of intervention adherence and clinical and behavioural outcomes and effects (Bartholomew Eldredge, et al., 2016; Carey, et al., 2018; Howlett, et al., 2019; Klonoff, 2019; Hagger, et al., 2020). In contrast, the information systems perspective is primarily concerned with: the design, development, deployment and evaluation of the technology itself (the mHealth app as a digital device and software); users' interactions with the mHealth app; the persuasiveness of the app and its software design features; and the effectiveness of the mHealth app as a digital mode of intervention delivery (Kasali, et al., 2017; Blandford, et al., 2018; Wilson, et al., 2018; Baretta, Perski and Steca, 2019; Haque, 2020).

While there are discernible differences in these two broad perspectives, both sides are fundamentally crucial to the success of mHealth (physical activity) behaviour change intervention consumer apps, and both offer relevant and necessary contributions to the design of said apps (Blandford, et al., 2018; Blandford, 2019a; 2019b). In light of this matter, the last decade has seen an increase in calls for multi- and interdisciplinary collaborative efforts that essentially combine and integrate both broad perspectives into a "holistic" perspective (Van Gemert-Pijnen, et al., 2011, p.1; Wang, et al., 2019, p.1). Walsh and Groarke (2019, p.38, p.46),

for instance, emphasise the need to "integrate [health] behavioural science with mobile (mHealth) technology to optimise health behaviour change interventions", and stress that a "strong multidisciplinary approach is required" to design and produce optimal solutions for health behaviour change. These sentiments are echoed by others, such as Mohr, et al. (2014, p.1) who underscore the need to "bridge the fields of [health] behavioural science and technology", and Murray, et al. (2016, p.848) who highlight that the mHealth behaviour change intervention app arena requires "fertile multidisciplinary collaborations that draw on insights and experience from multiple fields".

With calls to combine and integrate the two broad perspectives into a holistic perspective that emphasises a multi- and interdisciplinary collaborative approach, come calls for ongoing research into addressing the design related challenges associated with multi- and interdisciplinary mHealth app project teamwork (Kostkova, 2015; Blandford, et al., 2018; Blandford, 2019a; 2019b). These challenges are generally associated with four themes of mHealth behaviour change intervention apps: (1) their *design* (subthemes: behaviour change techniques (BCTs), persuasive systems design (PSD) principles, usability, mobile user experience design, adoption/engagement usage; gamification); (2) their underpinning *theory*, (3) their *effectiveness*, and (4) the *multi- and interdisciplinary collaborative approaches and processes* that guide their design, development and evaluation. These four challenges are independent, yet also interrelated. They often arise due to differences in perspectives stemming from heterogeneous disciplinary backgrounds, which lead to misunderstandings and conflicts of interest between persons from both sides when attempting to work collaboratively during the mHealth behaviour change intervention app design process (Carlile, 2002; 2004; Mohr, et al., 2014; Blandford, et al., 2018; Blandford, 2019a; 2019b; Bul, et al., 2020). Understanding these design related challenges and their emanation from and association with the lack of holistic approaches to guide and support effective multi- and interdisciplinary collaborations between relevant heterogeneous disciplines during the mHealth behaviour change intervention app design, development and evaluation process is important, particularly considering its impact on the effectiveness of said apps.

Integrating the two broad perspectives and their different approaches to designing, developing and evaluating mHealth (physical activity) behaviour change intervention consumer apps is, nevertheless, a challenging endeavour, and an ongoing and current predominant issue in this "young" (Mummah, et al., 2016, p.1) and "emerging interdisciplinary field" (Taj, Klein and

van Halteren, 2019, p.1). The "sheer magnitude" of this challenge in "getting all the necessary disciplines coordinated" is apparent in the remaining knowledge gaps and persisting paucity of holistic multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps (Blandford, 2019a, p.75; Taj, Klein and van Halteren, 2019; Bul, et al., 2020; Damen, et al., 2020; Sucala, et al., 2020; 2021). Calls for interdisciplinary collaborations therefore continue to increase, and are imperative to address to further progress and advance the mHealth intervention app arena, and especially considering that "these collaborations will benefit the field of digital health and support the design of interventions capable of not only temporar[il]y changing behaviours but also saving lives" (Sellak and Grobler, 2020, p.45).

A critical review of the handful of multi- and interdisciplinary approaches proposed within the last decade reveal them to exhibit several knowledge gaps and limitations. These concern: the structure and nature of current approaches; the use of different methods, frameworks, tools and taxonomies; misunderstandings and miscommunications that often arise from the unexpressed interpretive flexibility of certain terms/concepts; and the lack of practical guidance for translating and operationalising behaviour change techniques and persuasive systems design principles into engaging app design features. Current multi- and interdisciplinary approaches also lack the provision of "toolboxes"; that is, a "toolbox" of various tools, artefacts and methods from which collaborating team members can select and employ during the mHealth app design, development and evaluation process. Challenges also exist regarding interdisciplinary collaborative team compositions and functioning, and the importance of mutual respect and trust for respective member's perspectives, interests, motives, theories, approaches, methods, and expert contributions to mHealth (physical activity) behaviour change intervention app design, as well as a willingness to learn from one another in order to advance the emerging field. Furthermore, there is a need for better guidance and support in terms of interdisciplinary knowledge sharing and team communication, so that teams can better establish shared understandings and common ground to bridge differences in perspectives and overcome conflicts of interest. Considering the knowledge gaps and limitations of current approaches, there are opportunities for future research to address the main thesis problem:

*There exists a paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps.*

## 1.3 Goals of the Research

### 1.3.1 Research Questions

The study sought to answer the following main research question:

**Main Research Question:**

*How can interdisciplinary teams collaborate in the design, development and evaluation of mHealth physical activity behaviour change intervention apps?*

The main research question is broken down into the following four research sub-questions, which are incrementally explored and answered at various stages of the DSR process:

**Research Sub-Question 1:**

*What is the role of mobile technology in delivering interventions for promoting physical activity behaviour change?*

**Research Sub-Question 2:**

*What are the key challenges regarding the design, development and evaluation of mHealth behaviour change intervention apps for physical activity?*

**Research Sub-Question 3:**

*How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?*

**Research Sub-Question 4:**

*What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?*

### 1.3.2 Research Objectives

The following six research objectives guide the study, based on the design science research approach:

1. To illustrate the importance of health promotion behaviour change interventions in addressing the global noncommunicable disease and physical inactivity pandemics.
2. To investigate the role of mobile technology in delivering interventions for promoting physical activity behaviour change.
3. To investigate the key challenges regarding the design, development and evaluation of mHealth behaviour change interventions apps for physical activity.
4. To investigate a tri-composite community of practice, boundary object and knowledge boundary theoretical perspective to guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth behaviour change intervention apps.
5. To identify key themes and subthemes relevant to the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps.
6. To develop, evaluate and revise an interdisciplinary framework for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps.

## 1.4 Research Methodology

This research is conducted using a Design Science Research (DSR) approach and methodology (Hevner and Chatterjee, 2010; Weber, 2010; Vaishnavi and Kuelchler, 2015) and falls within the pragmatic paradigm (Goldkuhl, 2012a; Goldkuhl, 2020; Van der Merwe, Gerber and Smuts, 2020). As a problem-solving approach, DSR is applied to address this research study's complex, multifaceted and "wicked" real world practical design problem (Hevner and Chatterjee, 2010, p.11; Baskerville, et al., 2018). DSR guides the process of *designing* and constructing an innovative artefact that is *rigorously* informed by and grounded in existing design theory and knowledge, and iteratively evaluated and revised to ensure its *relevance* to real world practice in the application environment (Hevner, 2007; Van der Merwe, Gerber and Smuts, 2020). In this research study, the design artefact is in the form of a framework (an Interdisciplinary mHealth App Design Framework) that is constructed using the findings of a rigorous critical theoretical analysis of twenty existing multi- and interdisciplinary digital

health intervention development approaches drawn from the current knowledge base. After being developed, a semi-structured interview evaluation study is conducted with researchers and industry practitioners from the real world environment, of which the findings are used to interpersonally verify and inform the iterative revision and enhancement of the framework to ensure its quality and relevance to the real world practice domain.

Table 1.1 provides an overview of the research methodology applied in this study, outlining the strategies, methods, procedures and techniques utilised to answer the research questions.

*Table 1. 1: Research Methodology [Source: Researcher's own construction]*

| Research Structure | Applied Research Methodology |
|---|---|
| **Overall Research Paradigm** | Pragmatism |
| **Activity-Specific Paradigm** | Interpretivism, specifically Linguistic Interpretivism applied during artefact evaluation |
| **Perspectives** | Pragmatic, sociomaterial, symbolic interactionist and artefact-orientated |
| **Approach** | Design Science Research (DSR) approach |
| **Approach Methodology** | Vaishnavi and Kuechler's (2004; 2008; 2015) Design Science Research Methodology (DSRM), which includes five steps: (1) Awareness of Problem; (2) Suggestion (of a Tentative Design Solution); (3) Artefact Development; (4) Evaluation; and (5) Conclusion |
| **Problem Awareness** | • Literature reviews |
| **Suggestion (Tentative Design Solution)** | • An abductive cognitive reasoning strategy |
| **Artefact Development** | • A novel hybrid abductive, deductive and top-down inductive cognitive reasoning strategy<br>• Weick's (1989) theorising approach, comprising three components: (1) problem formulation; (2) thought trials; and (3) selection criteria<br>• A critical thematic and comparative theoretical analysis, using an adaptation of Braun and Clarke's (2006) six-step method and Corbin and Strauss's (2015) comparative analysis method<br>• Boell and Cecez-Kecmanovic's (2010; 2014) information systems hermeneutic search and acquisition process, which is used to identify and select the existing twenty multi- and interdisciplinary digital health intervention development approaches (as a secondary dataset)<br>• Crabtree and Miller's (1992) template approach, which frames the boundary object view applied during the critical theoretical analysis |
| **Artefact Evaluation** | • A hybrid deductive and inductive cognitive reasoning strategy<br>• Becker, Niehaves and Pfeifer's (2008a) qualitative DSR linguistic interpretivist approach, which incorporates ontological evaluation and interpersonal verification<br>• Research strategy: interview survey strategy<br>• Research instrument: virtual semi-structured interviews, with 31 researchers and industry practitioners spanning ten international countries<br>• Sampling technique: Snowball sampling<br>• Braun and Clarke's (2006) six-step qualitative thematic analysis method |

| | |
|---|---|
| | • Evaluation criteria: (1) construction adequacy; (2) language adequacy; (3) clarity<br>• Data validation techniques: prolonged data engagement; coding framework; reflexive journaling; memoing; diagramming; audit trails; thick descriptions; transparent reporting; and data triangulation (data person triangulation and data source triangulation). |
| **Conclusion** | • Reflection and abstraction as cognitive reasoning strategies |

Figure 1.1 provides a diagrammatic illustration of the overall research design, outlining the links between the (1) research chapters, (2) research chapters' purposes, (3) research methodology, (4) research questions, (5) research objectives, and (6) research chapter outputs.

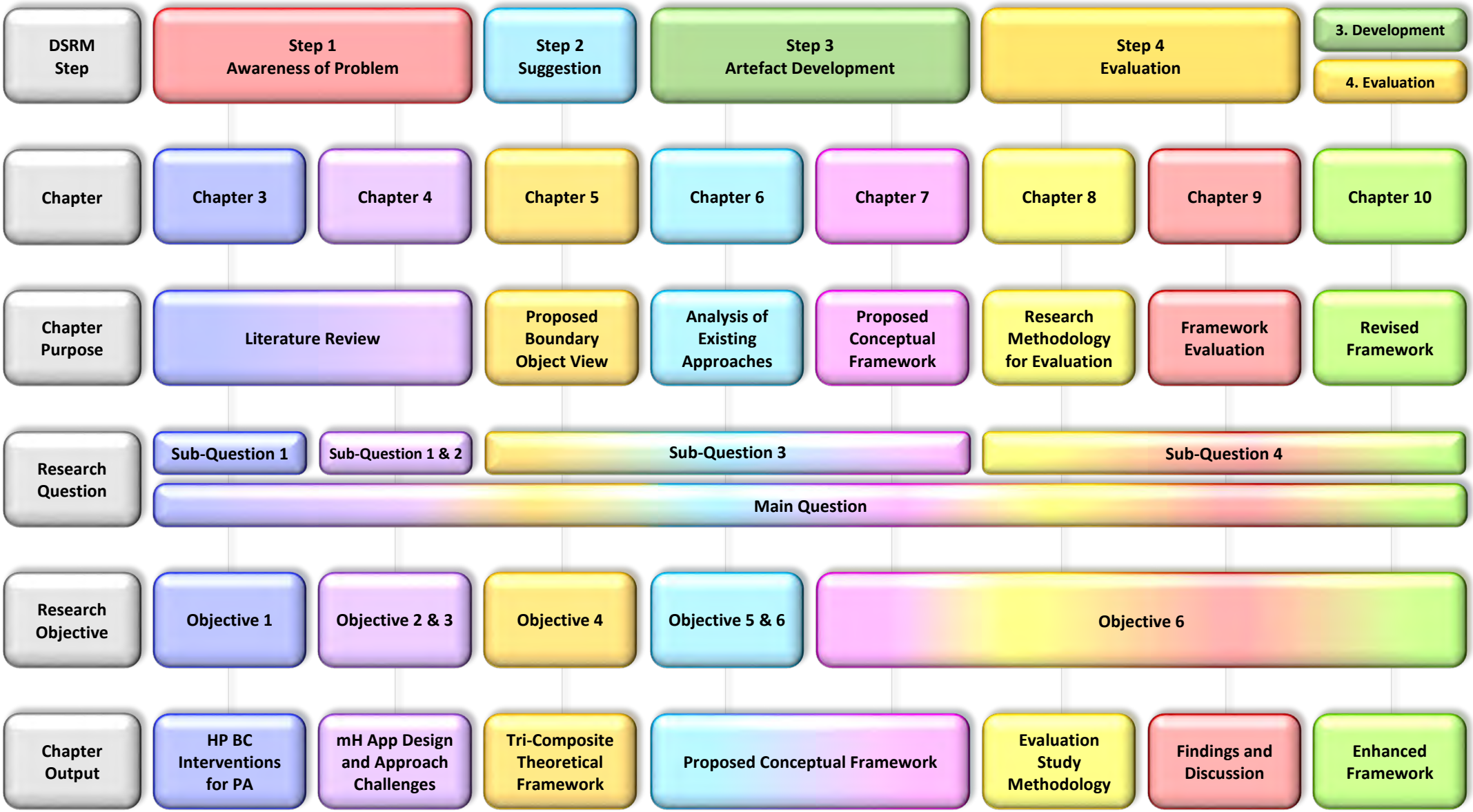



*Figure 1. 1: Overall Research Design*

*[Abbreviations: DSRM – Design Science Research Methodology; HP – Health Promotion; BC – Behaviour Change; PA – Physical Activity; mH – Mobile Health; App – Application][Source: Researcher's own construction]*

## 1.5 Research Scope

***Research Context Scope***

The health landscape context of this research study examines the global health status in terms of noncommunicable diseases (NCDs) and modifiable health risk behaviours, specifically physical inactivity. The study is further scoped to the health promotion field with a focus on the design of health promotion (physical activity) behaviour change interventions delivered to individuals at the dual intra-interpersonal socioecological levels of health promotion.

The digital health landscape context of this research study is scoped to the consumer health informatics (CHI) subfield within the broader health informatics field. In terms of digital health technologies, this research is delineated to the mobile health (mHealth) arena and focuses on mHealth consumer apps, specifically apps that can be downloaded and installed on mobile smartphone and tablet devices. The mHealth consumer apps under investigation include both research-based apps and commercial apps; the former of which are generally designed, developed and evaluated for specific research study purposes and are not released to the public outside of empirical studies (for example, doctoral studies), and the latter of which are publically released on commercial consumer app market stores (such as Google Play and Apple App Store). Given the physical activity health behaviour context of the research study, commercially released mHealth consumer apps are usually available internationally and tend to fall within the "health and wellness (lifestyle promotion)" category, and the "health and fitness" subcategory, on consumer app market stores (Google Play Store, 2021, p.1; Apple App Store, 2021, p.1). These delineations align with the research scope focusing on mHealth physical activity behaviour change intervention consumer apps delivered to individuals at the dual intra-interpersonal socioecological levels of health promotion.

***Research Problem Scope***

The context of the research problem is primarily framed through the lens of design. Design, in this research study, is concerned with the conceptualisation, iterative development, formative testing and evaluation of mHealth promotion (physical activity) behaviour change intervention consumer apps. Throughout the research study, references made to the mHealth app "design, development and evaluation process", implies the development and evaluation activities are viewed through the lens of design. This indicates the exclusion of development activities pertaining to coding and programming, which falls within the field of computer science. In

addition, matters concerning database design, privacy, security, information architecture, networking and connectivity are delineated out of the main research scope.

## 1.6 Research Significance

In light of the global NCD and physical inactivity pandemics, mHealth promotion intervention apps provide a powerful means of motivating, empowering and supporting individuals through processes of changing their modifiable health risk behaviours and daily lifestyle patterns (Blandford, 2019b; Kickbusch, 2019; WHO, 2019; De Cocker, 2020; Blagden, et al., 2021). The short- and long-term failings of mHealth intervention consumer apps to effectively promote behaviour change, such as physical activity, stem from complex design challenges and poor product design solutions produced through inefficient interdisciplinary team collaborations and inadequate design, development and evaluation project processes (Blandford, et al., 2018; Perski, et al., 2018; Blandford, 2019a; 2019b; Gao and Lee, 2019; Taj, Klein and van Halteren, 2019; Walsh and Groarke, 2019). To enhance the output product design and effectiveness potential of mHealth physical activity behaviour change intervention apps, better interdisciplinary approaches are required for guiding and supporting heterogeneous team members through the collaborative design, development and evaluation process of said apps (Blandford, 2019a; 2019b; Taj, Klein and van Halteren, 2019; Bendtsen, et al., 2020; Bul, et al., 2020; Damen, et al., 2020; Sellak and Grobler, 2020; Sucala, et al., 2020; 2021). In mHealth intervention app project environments, interdisciplinary actors (stemming from a diversity of practice communities), boundary objects and supporting artefacts, and knowledge processes are indispensable to the production of app products, and are complexly and intricately entangled. The mHealth Intervention App Design Framework produced from this research study leverages this entanglement by proposing that interdisciplinary team members utilise and create a variety of boundary objects and supporting artefacts to support their heteropraxial activities and knowledge sharing practices during the collaborative design, development and evaluation process, resulting in more efficient project team collaborations and more effective product output design solutions. The framework provides a reference model for interdisciplinary teams of academic, industry and/or academic-industry collaboration projects in guiding and supporting their applied collaborative process of designing, developing and evaluating mHealth physical activity behaviour change intervention consumer apps. As a reference model, various components of the framework can be purposefully employed, adapted and operationalised to inform practice within any given mHealth physical activity behaviour change intervention consumer app project context.

## 1.7 Summary of Results

The key results of the research thesis are as follows:

***Problem Formulation***

The worldwide NCD pandemic and its associated premature mortality rates and socioeconomic burden has spurred efforts by global institutions such as the WHO and UN to develop and publish health promotion strategies, policies, guideline recommendations and interventions aimed at targeting reductions in leading modifiable health risk behaviours such as physical inactivity. Despite considerable efforts, the physical inactivity pandemic continues to grow across low-, middle- and high-income countries. Every year, four to five million deaths could be averted if the global population were more physical active (Strain, et al, 2020; WHO, 2020c). In addressing these pandemics, digital and mobile technologies offer a powerful means of delivering health promotion behaviour change interventions to individuals across the world, with mHealth promotion (physical activity) behaviour change intervention apps becoming increasingly popular in recent years.

Key challenges, however, exist in terms of the design, development, evaluation and effectiveness of mHealth (physical activity) behaviour change intervention apps. These design related challenges stem from the discernible divide between health and technology, and deficiencies in the multi- and interdisciplinary collaborations between multiple relevant diverse disciplines, all of which are necessary in contributing to the design, development and evaluation of effective mHealth (physical activity) behaviour change intervention consumer apps. To produce better designed and more effective app product solutions, there is a need to integrate the spheres of health and technology, and develop "holistic" approaches for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps (Wang, et al., 2019, p.1). A paucity of such approaches exist in the current knowledge base. Given the indispensably intricate entanglement of actors, objects, knowledge and activities in mHealth intervention app projects, a boundary object view which emphasises the use and creation of boundary objects and supporting artefacts in guiding and supporting interdisciplinary teams in carrying out heteropraxial activities and knowledge sharing practices during the collaborative mHealth app design, development and evaluation process is necessary, and can contribute to the production

of better designed, more effective apps that can help motivate and empower more people towards leading healthier lifestyles.

***Theoretical Development***

The process of developing the mHealth Intervention App Design framework applies Weick's (1989) three-component theorising approach in conjunction with a hybrid (abductive, deductive and top-down inductive) cognitive reasoning strategy to conduct a critical thematic and comparative analysis on a selection of existing multi- and interdisciplinary digital health intervention development approaches. In going through Weick's (1989) process, firstly, the problem is formulated and clearly understood. Secondly, thought trials are employed as a mental tool for generating conjectures and conducting trial-and-error thought experiments on a heterogeneity of product kernel theories using creativity and disciplined imagination. Thirdly, selection criteria are used with Boell and Cecez-Kecmanovic's (2010; 2014) information systems hermeneutic search and acquisition approach to frame the process of selecting the secondary dataset. Selection criteria, together with Crabtree and Miller's (1992) template approach, are used as an analytical and critical lens for conducting the critical analysis. Selection criteria ensure consistency when selecting and analysing approaches.

The template used to analyse the selected existing approaches is framed through the proposed tri-composite theoretical framework (tentative design solution), namely the boundary object view, which constitutes an amalgamation of community of practice, boundary object and knowledge boundary theory. The template outlines nine criteria that guides the process of identifying and extracting explicit and latent actor, boundary object and supporting artefact, knowledge and process activity themes and subthemes from the selected existing approaches.

Twenty existing multi- and interdisciplinary digital health intervention development approaches are selected from the current knowledge base, and categorised into four perspectives: (1) a health perspective, (2) an information systems/technology perspective, (3) a partnership perspective, and (4) an integrative perspective. Through the critical thematic and comparative theoretical analysis, six main themes emerge pertaining to: (1) actors; (2) the design, development and evaluation process; (3) boundary objects and supporting artefacts; (4) knowledge; (5) the project boundary; and (6) outcomes. These six themes (and their comprising subthemes) form the theoretical foundation, components and subcomponents of the proposed conceptual mHealth Intervention App Design Framework.

***Empirical Investigation***

The proposed conceptual mHealth Intervention App Design Framework is evaluated using a qualitative DSR linguistic interpretivist approach to assess the (1) construction adequacy, (2) language adequacy, and (3) clarity of the framework. Virtual semi-structured one-on-one interviews are conducted with 31 knowledgeable and experienced academics/researchers and industry/commercial practitioners spanning ten international countries, including Austria, New Zealand, Australia, Sweden, Finland, Ireland, Singapore, Scotland, Belgium and Portugal.

***Research Outcome***

An evaluation criteria revision matrix is used to compare the proposed conceptual mHealth Intervention App Design Framework with the analysed findings from the interview evaluation study, to determine which framework components and subcomponents require revision and modification. Various minor, moderate and major revisions are made accordingly based on any identified discrepancies, and the interview evaluation study findings are used to inform the revision and medication of an enhanced mHealth Intervention App Design Framework, which is the final and primary DSR artefact contribution of the research study.

## 1.8 Thesis Organisation

The thesis chapters are organised as follows:

***Chapter 1: Research Introduction***

This chapter introduces the research study. The research context, rationale and problem statement is outlined. The research goals, methodology, scope and significance are presented. The chapter draws to a close with a summary of the research findings.

***Chapter 2: Research Structure***

This chapter outlines and discusses the research paradigm, philosophy, approach and methodology used to conduct the research study and answer the research questions.

***Chapter 3: The Health Landscape: Health Promotion and the Physical Activity Domain***

This chapter introduces the health landscape context of the research. The significance of the global NCD and physical inactivity pandemics are described and evidenced, the relevance of

health promotion behaviour change interventions in addressing these pandemics is discussed, and the socioecological model of health promotion is presented. With a scoped focus on health promotion physical activity behaviour change interventions delivered to individuals at the dual intra-interpersonal socioecological levels, key design considerations are outlined, concerning theories, determinants and correlates, and behaviour change techniques. The chapter concludes by outlining key challenges in the design of health promotion physical activity behaviour change interventions at the dual intra-interpersonal socioecological levels.

***Chapter 4: Digital mHealth: Using Technology to Deliver Health Promotion Interventions for Physical Activity Behaviour Change***

This chapter introduces the digital health landscape context of the research and outlines the main thesis problem. The research is positioned within the consumer health informatics subfield and the mHealth technology arena. The growing prevalence and popularity of mHealth consumer apps as a powerful mode for delivering health behaviour change interventions at the dual intra-interpersonal socioecological levels is presented. Challenges in the design of mHealth behaviour change intervention consumer apps are outlined, and emphasis is given to the paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps, as well as the increasing calls or novel and better approaches.

***Chapter 5: A Boundary Object View to the Interdisciplinary Collaborative Design of mHealth Behaviour Change Intervention Apps***

This chapter introduces and justifies the proposal of a novel boundary object view to addressing the paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps. The tri-composite theoretical framework (boundary object view) is presented, and the three community of practice, boundary object and knowledge boundary theories are discussed and justified as appropriate to address the thesis problem.

***Chapter 6: A Critical Analysis of Multi- and Interdisciplinary Digital Health Intervention Development Approaches***

This chapter introduces the theorising research approach and conducts the critical thematic and comparative theoretical analysis on twenty multi- and interdisciplinary digital health

intervention development approaches selected from the knowledge base. The chapter aims to identify key community of practice, boundary object and knowledge boundary themes and subthemes relevant to the interdisciplinary design of mHealth (physical activity) behaviour change intervention apps.

***Chapter 7: A Proposed Framework for Guiding the Interdisciplinary Collaborative Design of mHealth Intervention Apps for Physical Activity Behaviour Change***

This chapter develops and proposes the conceptual mHealth Intervention App Design Framework based on the thematic findings of the critical theoretical analysis. The framework comprises four main components, namely (1) actors; (2) an interdisciplinary collaborative process; (3) boundary objects and supporting artefacts; and (4) knowledge, and two supplementary components, namely (1) the project boundary; and (2) outcomes. The thematic relationships between the framework components are discussed.

***Chapter 8: Research Methodology for Framework Evaluation***

This chapter presents and describes the research methodology applied in evaluating the conceptual mHealth Intervention App Design Framework. It discussed the: qualitative DSR linguistic interpretivist approach; interview survey strategy; virtual semi-structured interview instrument; data collection and analysis methods; data validation; and ethical considerations.

***Chapter 9: Findings and Discussion***

This chapter presents the findings and discussion of the interview evaluation study. The main thematic finding discussions cover: (1) mHealth physical activity behaviour change intervention app projects; (2) goals and objectives; (3) actors; (4) the interdisciplinary collaborative process; (5) objects and supporting artefacts; (6) knowledge; and (7) key challenges and opportunities for future improvement. The thematic relationships are described.

***Chapter 10: An Enhancement of the Interdisciplinary mHealth App Design Framework***

This chapter evaluates the conceptual mHealth Intervention App Design Framework by comparing it against the interview evaluation study findings. Various minor, moderate and major revisions are made to the framework and a revised, modified and enhanced mHealth Intervention App Design Framework is presented as the final research artefact contribution.

***Chapter 11: Conclusion***

This chapter concludes the research study. It outlines the theoretical, practical and methodological contributions. The implications of the research are presented, reflections are performed, limitations described, and opportunities for future research are identified. The chapter closes with a succinct summary of the research study.

# Chapter 2

## Research Structure

*Research is a vital tool for solving problems, addressing societal issues and gaining knowledge; a powerful tool that... researchers must have a proper understanding about its elements and processes, [namely] the research paradigm, methodology, design and method[s].*

*– Okesina (2020, p.58) –*



## 2.1 Introduction

The previous chapter outlined the aims of this research study, including the problem statement, research questions and research objectives. This chapter describes the research process followed to answer the research questions and achieve the research objectives. As discussed in Chapter 1, the main research question asks *"How can interdisciplinary teams collaborate in the design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*. The overall research process adopted to answer the research questions and meet the research objectives outlined in Chapter 1 is illustrated in Figure 2.1. In this chapter, Section 2.2 discusses different research paradigms, philosophical perspectives and research approaches available, and justifies the selection of pragmatism as the paradigm and philosophical perspective, and Design Science Research (DSR) as the approach, applicable to this research study. Thereafter, Section 2.3 details the research design, covering the DSR approach followed, the DSR methodology, the cognitive reasoning strategy and theorising approach, and the DSR cycles. Section 2.4 outlines the evaluation of a DSR project, covering the DSR guidelines and the DSR communication and publication schema, followed by Section 2.5, which summarises the overall research process.

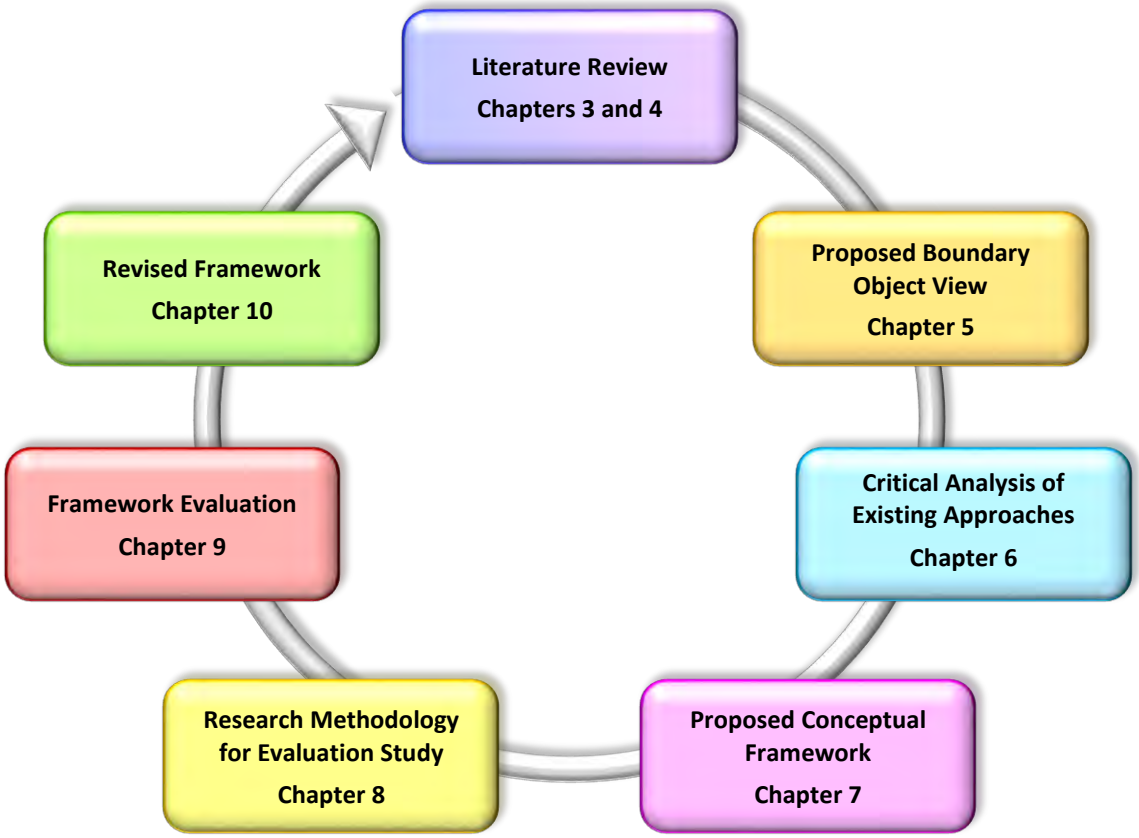



*Figure 2. 1: Overall Research Process [Source: Researcher's own construction]*

## 2.2 Research Paradigm, Philosophy and Approach

### 2.2.1 Research Paradigm and Philosophy

This study adopts pragmatism as the overarching paradigm and philosophical worldview. When conducting research, researchers adopt "basic belief system[s]" referred to as paradigms when making sense of, investigating and interpreting phenomena (Guba and Lincoln, 1994, p.107). A paradigm represents a set of fundamental assumptions, concepts, values and practices that constitutes a commonly held way a community can view reality and make sense of phenomena under investigation (Hirschheim and Klein, 1989). Considering that human perceptions of reality and truthful existence are arguably fallible given their conception and interpretation through sensory awareness and the socially-constructed worldviews of the conscious mind (Blavatsky, 1888), a paradigm provides a framework based on underlying philosophical assumptions that allows for the conducting of valid and defendable research within a specific discipline and delineated context (Burrell and Morgan, 1979). The four main philosophical assumptions underpinning paradigms are ontology (being), epistemology (knowing), axiology (acting), and methodology (conducting) (Guba and Lincoln, 1994; Heron and Reason, 1997). Figure 2.2 depicts the four philosophical assumptions that implicitly and explicitly influence the way a researcher goes about executing research (Guba and Lincoln, 1994; Heron and Reason, 1997; Creswell, 2013; Okesina, 2020):

1. *Ontological assumptions:* The nature of reality/being and what exists.
2. *Epistemological assumptions:* The nature and forms of knowledge, and how knowledge is acquired, validated and disseminated; a researcher's relationship with knowledge.
3. *Axiological assumptions:* The value, intrinsic worthiness and purpose of human inquiry, and how values influence a researcher's ethical practices, interpretations and potential biases.
4. *Methodological assumptions:* The research design, approaches, methods and techniques used in a research process to address the defined research questions and objectives.

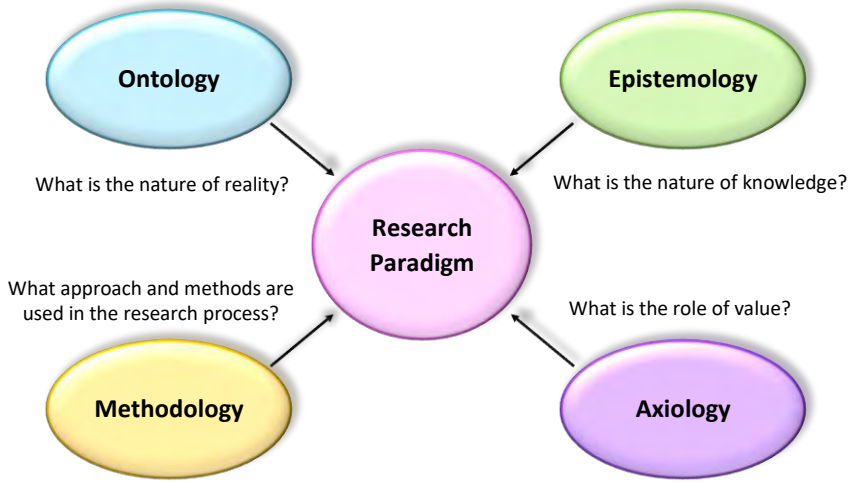



*Figure 2. 2: Philosophical Assumptions Underlying Research Paradigms [Source: Researcher's own construction, adapted from Guba and Lincoln (1994), Heron and Reason (1997), Creswell (2013) and Okesina (2020)]*

Over the years, information systems literature has been largely influenced by the adoption of four prevalent paradigms, namely (Avenier and Thomas, 2015):

1. ***Positivism***

   The positivist paradigm is based on the ontological assumption that reality exists independently of human action, and that the nature of reality is universal, ordered and granular (Weber, 2004). Epistemologically, positivism employs the scientific method and aims to produce law-like, objective knowledge generalisations that are observable, measurable and factual, and often seek to determine causal explanations and predictions using numerical data (Guba and Lincoln, 1994). In terms of axiology, the researcher is deemed detached, neutral and independent from the phenomenon under investigation, maintaining an objective and value-free stance (Saunders, Lewis and Thornhill, 2016). Methodologically, positivism generally employs the scientific method to define and test hypotheses, quantitatively measures characteristics of subjects and objects under investigation (as variables), and typically utilises highly structured, deductive and large sample-based methods (Weber, 2004). Positivism is appropriate for (natural scientific) research studies that aim to reduce/simplify, manipulate and observe measurable variables, test hypotheses and causal relationships, and specify explanations and predictions in order to produce law-like generalisations of reality (Bryman, 2012).

2. ***Interpretivism***

   The interpretivist paradigm views the nature of reality as rich, complex, inseparable from human life-world experience, and relativist and socially constructed through language,

culture, consciousness, shared meanings and other artefacts (Weber, 2004; Avenier and Thomas, 2015; Okesina, 2020). The existence of multiple realities, meanings and interpretations is assumed, and it is viewed that an intersubjective reality comprises a dynamic flux of processes, experiences and practices (Saunders, Lewis and Thornhill, 2016). Epistemologically, interpretivism seeks to generate knowledge that provides new, deeper and contextual understandings of subjective realities, by focusing on peoples' personal narratives, stories, perceptions, sensemaking and interpretations of experiences and phenomena (Avenier and Thomas, 2015). In terms of axiology, the researcher forms part of the research process and is instrumental to data analysis, interpretation and knowledge generation (Saunders, Lewis and Thornhill, 2016). The researcher assumes a subjective and value-bound position, and ought to be reflexive throughout the research process to guard against personal biases (Okesina, 2020). In terms of methodology, interpretivism generally aims to gain an in-depth, deeper, richer and contextual understanding of phenomena and defined settings by employing qualitative methods that allow for emic, inductive reasoning with small sample sizes (Saunders, Lewis and Thornhill, 2016). Interpretivism is appropriate for (social scientific) research studies that aim to gain a deeper (generally contextual) understanding of inherently complex human thoughts, perceptions, beliefs, attitudes and behaviours, as well as gain insight into human sensemaking and meaning-making, in order to generate knowledge and develop theory pertaining to human lived experience and social reality (Bryman, 2012).

**3.** ***Critical realism***

In critical realism, reality is assumed to be layered (through empirical, actual and real levels), intransient with causal mechanisms and objective structures, and viewed as existing externally and independently of human thoughts, beliefs and knowledge (Avenier and Thomas, 2015). Critical realism embraces epistemological relativism, viewing knowledge as historically situated (as a product of its time) with historical causal explanations, and deeming social facts as social constructions agreed upon by people (Guba and Lincoln, 1994). With regard to axiology, the researcher acknowledges their own biases created by their upbringing, socio-cultural experiences and worldviews, tries to minimise biases and errors, and attempts to remain as objective as possible (Saunders, Lewis and Thornhill, 2016; Okesina, 2020). Critical realist research is value-laden and seeks to emancipate people from social, cultural and political domination by making unconscious values and social structures more visible (Carlsson, 2011). In other words,

the critical realistic paradigm is predominantly concerned with challenging societal values and power dynamics with the intention to promote social justice as a means of creating a fairer, more impartial and harmonious world, where people are encouraged to create consciously-driven changes within their social and economic circumstances (O'Mahoney, Vincent and Harley, 2018). Methodologically, retroductive reasoning is often applied, and a range of methods can be employed to carry out in-depth historical situated analyses of pre-existing structures and emerging agency, as long as the methods appropriately fit the deconstruction and emancipation of phenomena under investigation (Bryman, 2012; Saunders, Lewis and Thornhill, 2016). Critical realism is appropriate for (social scientific) research studies that aim to identify, describe and contextually understand the causal mechanisms and structures that generate the social world in order to address and change them, so that (social) inequalities and injustices can be counteracted and rectified (Bryman, 2012).

**4.** ***Pragmatism***

Pragmatism holds the ontological assumption that there exists an external, richly complex and non-singular reality that is constantly interpreted, debated and renegotiated in light of its usefulness in various contexts and situations (Saunders, Lewis and Thornhill, 2016). According to Goldkuhl (2012b, p.12), pragmatism's ontology can simply be described in terms of "symbolic realism". Other researchers, such as Maarouf (2019), argue that the definitive ontological position of pragmatism remains unclear and ill-defined. Nevertheless, generally speaking, the nature of reality in pragmatism is viewed in terms of practical actions and situations, associated effects and consequences, and is assumed to exist as a flux of processes, experiences and practices (Saunders, Lewis and Thornhill, 2016). Pragmatism is essentially a problem-solving paradigm that aims to provide explanations for the "best" or "optimal" possible solutions to practical real world problems (Smith, 1990, p.433), where ideal and exclusive solutions are unlikely, yet "what works" and is regarded as useful is deemed adequate for the given purpose and context (Creswell, 2013, p.28). In contrast to positivism, it rejects absolutism and utilises an integrated approach intended to interpret truth and utility that aims to produce normative knowledge that prescribes practical and appropriate means of achieving desired outcomes (Smith, 1990; Avenier and Thomas, 2015).

Epistemologically, knowledge holds meaning in specific contexts, valid theories are those that enable successful actionable practice, and contributing knowledge that supports problem-solving and informs future practice is valued (Saunders, Lewis and Thornhill, 2016). Axiologically, research is value-driven and reflexive, is initiated and sustained by a researcher's beliefs, doubts and "intuitions", and the knowledge generated reflects both the researcher's and participants' views (Smith, 1990, p.434; Creswell, 2013). In terms of methodology, pragmatism provides a flexible approach to inquiry where the researcher is free to adopt objective and subjective points of view at different aspects of the research process, and is able to select and combine a mixture of qualitative and quantitative methods and techniques depending on their suitability to the study purpose and objectives (Smith, 1990; Creswell, 2013). Pragmatism is appropriate for (social scientific) research studies that intend to address practical problems by seeking to investigate and understand the practical effects of human ideas, conceptions, objects and actions, and that aim to contribute action-orientated knowledge that works satisfactorily in practice (Bryman, 2012; Goldkuhl, 2012a; 2012b). Pragmatism is also appropriate for studies that aim to provide prescriptive and constructive knowledge that can be used to influence and improve practice (such as frameworks and guidelines, as is the case in this research project) (Goldkuhl, 2012a; 2012b).

A summary of the ontological, epistemological and axiological assumptions underpinning these four main worldviews, along with the typical methods applied in these perspectives, is provided in Table 2.1. The philosophical assumptions relevant to this particular research study are highlighted in yellow.

*Table 2. 1: Summary of the Philosophical Assumptions of Four Prevalent Information Systems Research Paradigms [Source: Researcher's own construction, adapted from Weber (2004), Carlsson (2011), Bryman (2012), Goldkuhl (2012a; 2012b), Avenier and Thomas (2015), and Saunders, Lewis and Thornhill (2016)]*

| **Research Paradigms** | **Philosophical Assumptions** | | | |
|---|---|---|---|---|
| | **Ontology** | **Epistemology** | **Axiology** | **Methods** |
| **Positivism** | • Single, external, ordered reality<br>• Universal<br>• Independent of human action and beliefs | • Objective<br>• Independently observable<br>• Observe phenomena using clearly defined and measurable values<br>• Causality, predictions | • Value-free<br>• Detached, neutral and independent<br>• Objective | • Quantitative<br>• Deductive<br>• Highly structured, large data samples<br>• Experimental<br>• Statistical<br>• Hypothesis testing |

| | | | | |
|---|---|---|---|---|
| **Interpretivism** | • Complex, rich<br>• Socially-constructed<br>• Multiple meanings, interpretations and realities<br>• Flux of processes, experiences and practices<br>• Inseparable of human action and beliefs | • Subjective sensemaking, meanings and interpretations<br>• Undetached<br>• Observe details of contextualised social phenomena | • Value-bound<br>• Contextual understanding<br>• Influenced by researcher's values<br>• Intersubjective<br>• Acknowledges and minimises potential biases<br>• Reflexive | • Qualitative<br>• Inductive<br>• Hermeneutics<br>• Contextual investigation<br>• In-depth inquiry<br>• Ethnography and grounded theory<br>• Small samples<br>• Focus groups<br>• Interviews |
| **Critical Realism** | • External, intransient reality<br>• Layered (empirical, actual, real)<br>• Independent of human action and beliefs<br>• Objective structures<br>• Causal mechanisms | • Relativism<br>• Historically, socially and culturally-situated<br>• Facts as social constructions<br>• Historical causal explanations | • Value-laden<br>• Acknowledges and minimises biases and errors<br>• Attempts to remain as objective as possible | • Retroductive<br>• In-depth and historically-situated<br>• Ethnographic and grounded theory methods<br>• Questionnaires<br>• Interviews<br>• Case studies |
| **Pragmatism** | • Complex, rich, external reality<br>• Multiple realities<br>• Renegotiation<br>• Practical effects and usefulness of ideas, actions and situations<br>• Symbolic realism<br>• Flux of processes, experiences and practices | • Problem-solving, practice focus<br>• Objective and subjective<br>• Prescriptive<br>• Better, satisfactory practical solutions<br>• Theories enable action<br>• Practical meaning in context | • Value-driven<br>• Initiated and sustained by researcher's beliefs, doubts and useful intuitions<br>• Acknowledges and minimises potential biases<br>• Reflexive | • Follows the research problem<br>• Inductive and deductive<br>• Qualitative and/or quantitative<br>• Multiple and/or mixed<br>• Methods for finding practical solutions and outcomes to problems |

As indicated in Table 2.1, the pragmatic and interpretivist paradigms and philosophical perspectives align best with the problem statement, research questions and research objectives discussed in Chapter 1. Considering that the main research problem is defined in terms of a real world, practical and complex multi- and interdisciplinary design issue, and the main research objective aims to develop a framework that contains practical, action-orientated and prescriptive knowledge, pragmatism is deemed the most suitable paradigm for guiding the research process. Powell (2001, p.884) highlights that "to a pragmatist, the mandate of science is not to find truth or reality, the existence of which are perpetually in dispute, but to facilitate human problem-solving"; a notion befitting with the aims of this study. Pragmatism enables the researcher to assume a flexible problem-solving perspective when investigating the phenomenon of interest and constructing the proposed framework. Ontologically, the complex, rich and multiple realities of actors positioned within diverse communities of practice, and the dynamic fluxes of processes, experiences and practices between them, are acknowledged and respected (Saunders, Lewis and Thornhill, 2016; Okesina, 2020). This pluralist view that

recognises the constant renegotiation of reality and emphasises the practical usefulness ad effects of ideas and actions is relevant to the multi- and interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention consumer app projects. In information systems and design research, pragmatist thinking supports the generation of useful practice-orientated knowledge; practical knowledge that can be prescriptive or constructive for practical improvements (Goldkuhl, 2012a).

Epistemologically, the problem-solving and practical focus of pragmatism allows for the generation of knowledge and theory that is concerned with knowledge about the actors, processual activities, heteropraxial collaborative practices, and material action-objects and artefacts applicable to the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps (Goldkuhl, 2012a). Axiologically, the researcher is driven by their own intuition, beliefs, tacit knowing and doubts; described by Peirce, et al. (1958, p.499) as an "association by interest" that largely involves guessing, speculation, imagination, trial-and-error experimentation and creative conceptualisation (Peirce, et al., 1931; 1933; Gold, et al., 2011). This pragmatic process requires the researcher be reflexive and transparent, and actively acknowledge and attempt to minimise any potential biases, in order to theorise and produce theory that is credible and trustworthy (Smith, 1990; Saunders, Lewis and Thornhill, 2016). Methodologically, pragmatism is appropriate for this research study in that it does not assume a dogmatic position concerning the use of methods and techniques, yet rather adopts a pluralistic perspective that caters for the flexible employment and combining of various methods and techniques to best suit the research study purpose and empirical situation (Goldkuhl, 2012b; Saunders, Lewis and Thornhill, 2016; Okesina, 2020).

Within the overarching pragmatic paradigm adopted in this study, interpretivism is employed when evaluating the DSR artefact (framework). Pragmatism and interpretivism are regarded by some researchers as two distinct paradigms (Powell, 2001) and argued by other researchers as partially fusible and complementary in DSR studies (Blumer, 1969; Goldkuhl, 2012a; 2012b; Saunders, Lewis and Thornhill, 2016). In information systems and DSR studies, two prominent pragmatic and interpretivist fusions are the symbolic interactionist perspective (Goldkuhl, 2012a; 2012b) and the sociomaterial perspective (Orlikowski, 2007; Carlile, et al., 2013). Symbolic interactionism holds the view that humans interact with things based on the meanings they ascribe to those things; that the ascribed meaning of such things derives from their social interactions with others and society; and that the meanings of things are interpreted

by humans when dealing and interacting with things in specific circumstances (Blumer, 1969). Sociomaterialism (or sociomateriality) holds the view that humans and artefacts are inseparable in practice, that there exists a relational and "constitutive entanglement" between peoples' actions and the material objects (or technology) which they interact with in a socially constructed reality (Orlikowski, 2007, p.1444; Caccamo, 2020), and that knowing comes from humans sociomaterial entanglement and "direct material engagement with the world" (Carlile, 2013, p.36). The perspectives of both symbolic interactionism and sociomaterialism are implicit and explicit in this DSR research project, particularly when tentatively suggesting, constructing, evaluating and revising the design artefact solution (framework). Deng and Ji (2018) support the notion of a researcher adopting interpretivism during specific stages of the iterative design process, within an overarching pragmatic DSR study.

The framework is built on the premise that during the collaborative design process, heterogeneous community of practice actors interact with objects and other actors in a variety of given design contexts and design situations, and that their worldview interpretations of, and relations with, these objects and people influence the conceptualisation and construction of the resulting mHealth behaviour change intervention consumer app design solution. This is to say that within a social, practical, material and constructivist reality, the mHealth consumer app emerges as a design product outcome of the collaborative interdisciplinary project and process that involves actors from several independent, yet relevant, areas of specialisation. To put in other words, the mHealth intervention consumer app emerges from a complex entanglement of social, relational, material and symbolic interactionist practices between people (community of practice actors) and the artefacts (material, symbolic and technological site-specific objects and multi-site shared boundary objects) that they employ and utilise during the project's enacted interdisciplinary collaborative process (in practice).

### 2.2.2 Research Approach

This research study applies the Design Science Research (DSR) approach. In pragmatism there are a variety of information systems orientated methodological approaches available for conducting design-orientated research, including participatory research, Research through Design (RtD), Action Design Research (design-driven action research; ADR) and Design Science Research (DSR).

Participatory research methods are geared towards conducting research and creating solutions with people whose real-life world and meaningful actions are under investigation (Bergold and Thomas, 2012). An iterative approach to inquiry is of fundamental importance throughout the research process and requires constant, valuable input from relevant participants, through which collaborative, novel solutions arise (Kensing and Blomberg, 1998). These participatory approaches hence demand a stable supply of adequate resources and financing, and can take a significant number of years to ensure sound methodological adherence (Bergold and Thomas, 2012). Furthermore, ongoing and iteratively held participatory methods are required throughout the initial, developmental and evaluation phases of the research, which requires "researchers [to] spend a long time in the field" (Bergold and Thomas, 2012, p.13). This can lead to unexpected delays that negatively impact deadlines and can potentially affect the credibility and reliability of the research. These several reasons deem participatory research approaches unsuitable for use with this particular research study. Furthermore, participatory research methods do not necessarily aim to construct artefacts, whereas the main objective of this research study is to develop and propose an artefact in the form of a framework, which is better suited to a DSR approach.

Research through Design (RtD) is comparably more suitable in that it stresses design-based artefacts as outcomes intended to transform a defined situation from its current state to a preferred state (Zimmerman, Forlizzi and Evenson, 2007). RtD has gained popularity in human computer interaction studies, where insights into design practices embedded in the design process provide a better understanding of addressing "wicked problems" (Zimmerman, Forlizzi and Evenson, 2007, p.495). DSR exhibits several overlaps with RtD. RtD, however, is distinguishable in that it often focuses on commencing with a design problem and through the design process and experimentation with designers and researchers, research emanates (Basebelle and Halskov, 2012),. Whereas DSR allows the researcher to first gain an understanding of a specific research problem, along with the processes and concerns of practitioners in the related communities of practice, to develop a design-orientated artefact (Hevner and Chatterjee, 2010).

Design-driven action research, commonly referred to as Action Design Research (ADR), uses an interactive inquiry process to enable an active participatory approach to creating change, often within organisational and institutional contexts (Fendt and Kaminska-Labbe, 2011). In comparison, DSR provides a flexible, design-orientated approach to guide the creation of

innovative artefacts that encompass both material and process contributions within a broader range of application contexts (Hevner and Chatterjee, 2010). Several debates have transpired on the similarities and differences between ADR and DSR (Cole, et al., 2005; Iivari and Venable, 2009; Järvinen, 2007; Papas, O'Keefe and Seltsikas, 2012). ADR does not require an artefact to be a part of the design solution (Johannesson and Perjons, 2012) and can emerge as a "by-product of the research intervention" (Papas, O'Keefe and Seltsikas, 2012, p.156), whereas DSR adopts a problem-solving perspective with the specific aim of creating innovative artefacts intended to address practical problems using an iterative development and evaluative approach, and emphasises the artefact as the key research contribution, as is the case in this research study proposing a framework artefact contribution (Hevner and Chatterjee, 2010; Vom Brocke, Hevner and Maedche, 2020).

The nature of these other pragmatic approaches deems them unsuitable to the objectives and intended contributions of this research study. The DSR approach, however, provides appropriate methodological guidance for the development of a design-orientated artefact, along with design theory and practice processes, that enables the generation of a design solution that provides sufficient guidance for interdisciplinary design practitioners in achieving desirable mHealth consumer app project outcomes (Hevner, et al., 2018). DSR has become accepted as a research approach "consistent with the DS research processes employed in the IS discipline" (Peffers, et al., 2007, p.73) and has been applied in a range of information systems research dissertations and studies (Iivari, 2007; Wiafe, 2012; Harjumaa, 2014; Hermano and Stewart, 2014; Mthoko, 2016; Uppström, 2017; Baduza, 2020; Vom Brocke, et al., 2020).

Although justifiably an appropriate approach for this information systems research project, it should be acknowledged that there remains a debate amongst influential DSR researchers as to whether DSR falls within the pragmatic paradigm, or if it is a paradigm in its own right, encompassing its own ontological, epistemological, axiological and methodological assumptions (Hevner, et al., 2004; Hevner, 2007; Vaishnavi and Kuelchler, 2008; Goldkuhl, 2009; Hevner and Chatterjee, 2010; Weber, 2010; Alturki, Gable and Bandara, 2011; Goldkuhl, 2012a; Weber, 2012; Gregor and Hevner, 2013; Goldkuhl, 2020; van der Merwe, Gerber and Smuts, 2020). Nevertheless, an overview of the DSR literature demonstrates significant evidence for arguing DSR as a research approach within pragmatism, rather than applying it as a straight-out paradigm (Cole, et al., 2005; Hevner, 2007; Hevner and Chatterjee, 2010; Alturki, 2012; Goldkuhl, 2012a; Deng and Ji, 2018; Prat, Comyn-Wattiau and Akoka, 2014; Goldkuhl,

2020; van der Merwe, Gerber and Smuts, 2020). This is especially considering that the foundations and boundaries of DSR are yet to be agreed upon, clearly defined and universally accepted amongst prominent researchers in the DSR community (Weber, 2010; Hevner and Gregor, 2013; van der Merwe, Gerber and Smuts, 2020).

Despite these ongoing deliberations, the adoption of DSR allows for the moulding of a flexible and customisable methodological approach suited to a complex, ill-defined, and "real world messy" multi- and interdisciplinary research problem (Nagle, et al., 2020, p.1), where the creation of an absolute or perfect solution is impractical given the dynamic and multifaceted interactions betwixt the diverse engaging communities and the evolving, multidimensional nature of the field. Along with the development and evaluation of a proposed novel artefact, the DSR approach also allows the researcher to acknowledge the distinctive value of design theory and design knowledge as both inputs and outputs of the research study (Baskerville, et al., 2018). In addition, the DSR approach provides the researcher with the opportunity to investigate and ground their artefact contribution in existing descriptive and justificatory knowledge (such as kernel theories) and prescriptive knowledge (that is, to purposefully improve human mental and physical capabilities in a technology application context) (Baskerville, et al., 2018). Furthermore, the DSR approach is suitable for answering research questions that are orientated towards problem-solving and improvement, which generally ask questions along the lines of *"How can we develop X?"* or *"How can we develop X to resolve Y?"* (Thuan, Drechsler and Antunes, 2019, p.332), demonstrating its suitability for this research.

## 2.3 Research Design

### 2.3.1 The Design Science Research Approach

Design Science Research (DSR) provides a problem-solving approach that seeks to enhance human knowledge via the creation of innovative artefacts (such as frameworks) that aim to address design-related problems and improve design-related practice (Vom Brocke and Maedche, 2019). DSR aims to generate knowledge of how things can and should be constructed or arranged (that is, designed), usually by human agency, to achieve a desired set of goals (Vom Brocke, Hevner and Maedche, 2020). This knowledge is referred to as design knowledge; knowledge about innovative solutions to real world problems, and knowledge pertaining to means-end relationships between design problem and solution spaces (Vom Brocke, et al., 2020). Design research problems are notorious for exhibiting complex, multifaceted, ill-

defined and "messy" (Stolterman, 2008, p.1) or "wicked" characteristics (Rittel and Webber, 1973, p.160; Hevner and Chatterjee, 2010, p.11). In addition, design problems are largely argued as being subjectively interpretable, thus opening them to a range of diverse perspectives and potential suggestions, for which it is not possible to seek or attain an "optimal" design solution (Lee, Pries-Heje and Baskerville, 2011, p.3) or "best" design theory (Truex, Holmström and Keil, 2006, p.814). Therefore, in addressing wicked design problems, a design science researcher aims to develop and propose satisfying design artefact solutions that can be described as "satisfactory" (Hevner and Chatterjee, 2010, p.188) or "satisficing" (Simon, 1996, p.119; Lee, Pries-Heje and Baskerville, 2011, p.4). For the most part, novel proposed design artefact solutions and nascent design theory (Vaishnavi, Kuechler and Petter, 2017) tend to be in the form of "approximations" (Weick, 1995, p.385), and usually offer "partial" or "incomplete" design knowledge (Gregor and Hevner, 2013, p.338), which in DSR, is deemed a "good enough" (Simon, 1996, p.27) contribution to the "improvement" quadrant (Gregor and Hevner, 2013, p.345).

Design Science Research (DSR) has gained significant popularity within the information systems discipline over the last three decades (Nunamaker, Chen and Purdin, 1991; Walls, Widmeyer and Sawy, 1992; March and Smith, 1995; Hevner, et al., 2004; March and Storey, 2008; Hevner and Chatterjee, 2010; Johannesson and Perjons, 2012; Gregor and Hevner, 2013; Venable, Pries-Heje and Baskerville, 2016; Hevner, vom Brocke and Maedche, 2019; Vom Brocke, et al., 2020), after having originated from Herbert Simon's (1996) book, *The Sciences of the Artificial*. On the one hand, DSR allows researchers to draw kernel theories from the natural and behavioural sciences, theories which seek to explain and predict human behaviour, and which impact and are impacted by design considering that they inform the interactions among people, technology and organisations (Hevner, et al., 2004). On the other hand, DSR has roots in design sciences (that is, engineering and the sciences of the artificial), which seeks to solve problems by creating innovations that define and inform design-related practice, and which rely on existing kernel theories and justificatory knowledge through human creativity, intuition, experience, practice and problem-solving capabilities (Hevner, et al., 2004; Vaishnavi, Kuechler and Petter, 2017). The behavioural sciences and design sciences provide a root foundation for the DSR approach (as illustrated in Figure 2.3), and allows for the generation of design knowledge that is relevant to solving practical design problems (Hevner, et al., 2004). The dual (behavioural science and design science) scientific perspectives are suitable for investigating literature and conducting evaluations that require a broad

understanding of the relevant, yet complexly interwoven, elements associated with human cognitive capabilities, human social interactions, multi- and interdisciplinary design knowledge, behavioural change and technological design; all of which are apparent in this study's research problem and objective space.

Within the information systems discipline specifically, Hevner, et al. (2004) describe this dualistic (behavioural science and design science) approach as incorporating naturalistic and artificial research, which together can be used to develop and justify descriptive and prescriptive theories as well as guide the creation of novel and innovative artefacts intended to extend the technological and practical capabilities of humans, as a means for achieving man-made goals. The key output of a DSR study is an artefact. An *artefact* refers to an artificial construction conceived and developed by humans, as opposed to a naturally occurring solution (Simon, 1996). Baskerville, et al. (2018) and Vom Brocke, Hevner and Maedche (2020) specify two dominant types of contributions in DSR projects: design entities (for example, Hevner, et al., 2004; Vaishnavi, Kuechler and Petter, 2017) and design theory (for example, Gregor and Jones, 2007), and explain that what leads to these contributions is the conducting of design processes in search of solutions to design problems and theorising about such processes. Design entities and design theory contributions can, however, relate to one another in a DSR project (Gregor and Hevner, 2013). As indicated in Figure 2.3, DSR entity and theory contributions can be in the form of: (1) constructs (conceptual symbols and vocabulary for a domain or related domains); (2) methods (practices and algorithms); (3) models (representations and abstractions as a set of propositions conveying relationships between concepts or constructs); (4) instantiations (operationalisations of constructs, methods and models, such as a prototype); (5) frameworks (conceptual or real guides to serve as guidance or support); (6) architectures (high level structures of systems); (7) design principles (core principles and concepts to guide design); or (8) better design theories (March and Smith, 1995; Vaishnavi and Kuechler, 2004; Hevner, et al., 2004; Gregor and Hevner, 2013; Vaishnavi, Kuechler and Petter, 2017), and may constitute abstract or material form (Gregor and Hevner, 2013).

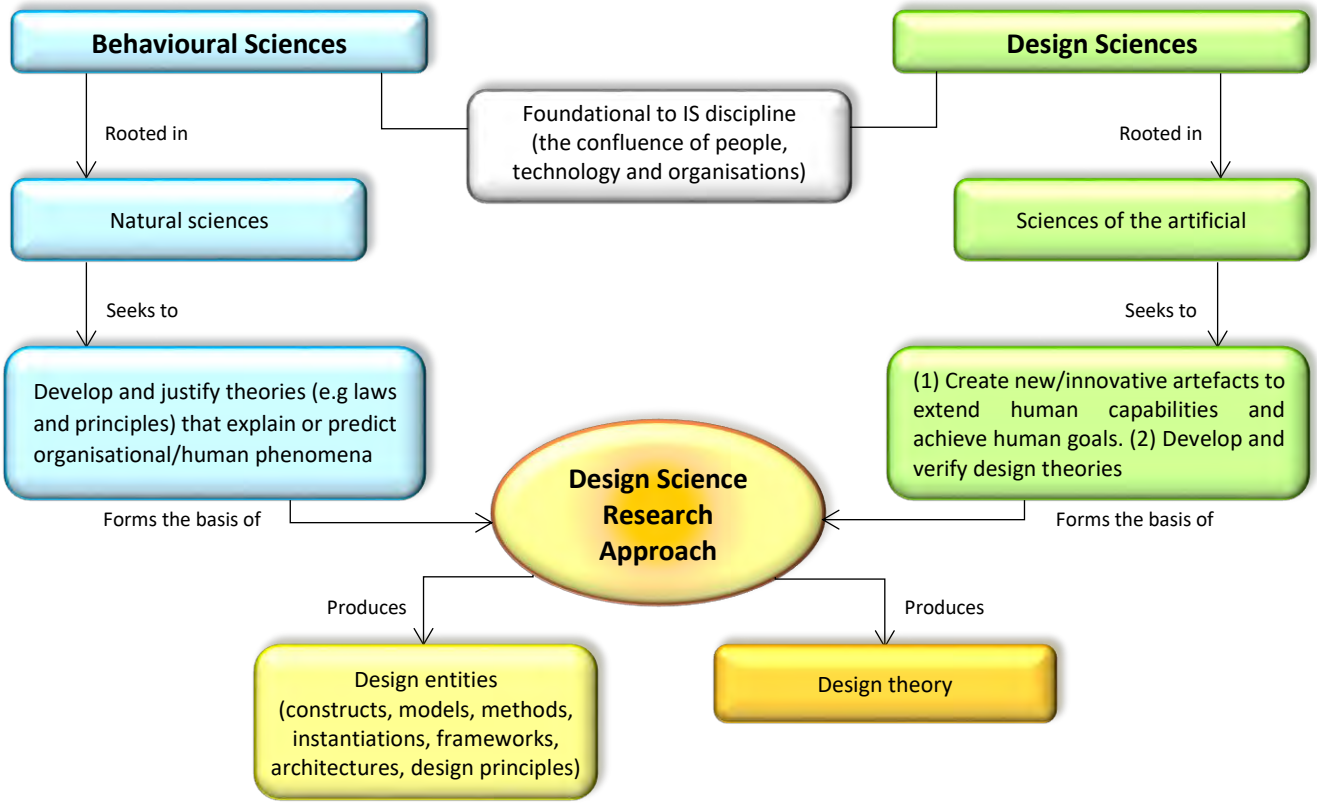



*Figure 2. 3: The Underpinnings of DSR [Source: Researcher's own construction, informed by March and Smith (1995), Hevner, et al. (2004), Hevner and Chatterjee (2010), and Vaishnavi, Kuechler and Petter (2017)]*

Applying the DSR approach in this study allows for the development and evaluation of an artefact in the form of a framework, which proposes a novel boundary object view to guiding and supporting interdisciplinary teams in the collaborative design, development and evaluation of mHealth consumer apps for physical activity behaviour change. In carrying out a DSR study, knowledge can be contributed in one of four distinct quadrants (illustrated in Figure 2.4). The four types of knowledge contribution are: (1) *invention* (new solutions that address newly discovered problems); (2) *improvement* (new solutions created in response to known problems); (3) *exaptation* (known solutions extended to address newly identified problems); and (4) *routine design* (known solutions used to address known problems) (Gregor and Hevner, 2013). The blue shaded circle in Figure 2.4 depicts this research study's contribution as falling within the "improvement" quadrant, specifically for the reason that this study's main objective seeks to propose a new solution to a known problem (Gregor and Hevner, 2013, p.345). In other words, this study aims to develop and propose a framework that adopts a novel tri-composite (community of practice, boundary object and knowledge boundary) theoretical perspective of a "wicked" multi- and interdisciplinary problem that other authors have similarly

identified and addressed (with other contributions) (Hevner and Chatterjee, 2010, p.11; Gregor and Hevner, 2013). When creating an innovative solution to a known problem, a valuable aspect of the DSR approach is that it allows design science researchers to build on existing parts of a solution, as well as combine, revise and extend on extant design knowledge (that is, existing theories, frameworks, models, constructs, methods, approaches or instantiations) (Vom Brocke, Hevner and Maedche, 2020); an activity that is applied in this research study.

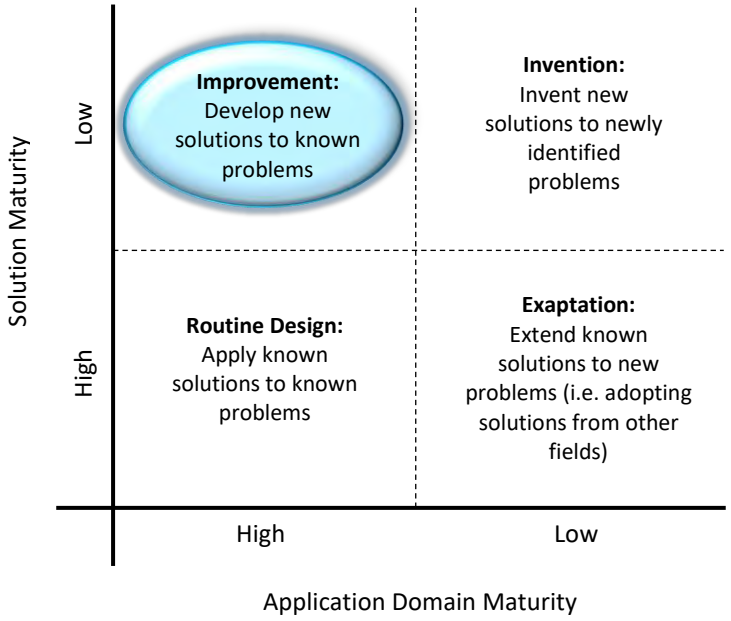



*Figure 2. 4: The DSR Knowledge Contribution Framework*
*[Source: Adapted from Gregor and Hevner (2013)]*

In essence, the DSR approach applied in this research study allows for the development of an artefact (framework) that seeks to improve how interdisciplinary teams collaborate in the process of designing, developing and evaluating mHealth intervention consumer apps for physical activity behaviour change. In carrying out this DSR approach, an appropriate and reliable DSR methodology should be outlined and applied.

### 2.3.2 The Design Science Research Methodology

Selecting and outlining a DSR Methodology (DSRM) provides further guidance for answering the research problem and achieving the research objective. The DSRM employed for guiding and conducting this research study is a widely applied five-phase process proposed by Vaishnavi and Kuechler (2004; 2008; 2015). An overview of the dominant DSR methodologies identified four possible frameworks and processes for conducting this research. Johannesson

and Perjons (2012) propose a method comprising five main activities: (1) explicate the problem; (2) define the requirements and outline the artefact solution; (3) design and develop the artefact; (4) demonstrate the artefact; and (5) evaluate the artefact. By adding an additional activity relating to the communication of a research artefact output and generated design knowledge, Peffers, et al. (2006; 2007) and Hevner and Chatterjee (2010) both propose a DSRM consisting of six steps: (1) identify and motivate the problem; (2) define the objectives for a solution; (3) design and develop the artefact; (4) demonstrate the artefact; (5) evaluate the artefact; and (6) communicate the research. Given that these three DSRM processes include a demonstration activity, none of them are suitable for this conducting this research. The five-step DRSM proposed by Vaishnavi and Kuechler (2004; 2008; 2015), however, is suitable for guiding this research study because it does not include a demonstration activity. As illustrated in Figure 2.5, Vaishnavi and Kuechler's (2004; 2008; 2015) DSRM comprises five process steps: (1) *awareness of the problem*; (2) *suggestion of a tentative design solution*; (3) *development of the artefact*; (4) *evaluation of the artefact*; and (5) *conclusion of the research*.

An elaboration on the details pertaining to each of the five DSRM steps performed in this study are as follows (in reference to Figure 2.5):

1. ***Awareness of the Problem:***

   The research problem is identified and defined in relation to a reference discipline (that is, information systems and digital health) (Vaishnavi and Kuechler, 2008; 2015). In DSR, research problems and questions are generally problem-solving focused (Vaishnavi, Kuechler and Petter, 2017), as specified in this study. The problem space is described and explicated, and the research problem is motivated for in terms of its relevance and significance as a practical real world, design-orientated problem (Peffers, et al., 2007). The specific research problem was introduced and delineated in Chapter 1, and the problem space will be explicated and expanded upon in Chapters 3 and 4 through literature reviews.

2. ***Suggestion of a Tentative Design Solution***

   A suggestion in the form of a tentative design solution is formulated; a creative step involving the defining and justifying of a novel proposition to address the defined research problem (Vaishnavi and Kuechler, 2004; 2008; 2015). In doctoral research, the tentative design solution should not present itself in existing research, and should offer a

new artefact and design knowledge contribution to the information systems discipline (Vaishnavi and Kuechler, 2008; 2015). Suggestions for a problem solution are generally drawn through abductive cognitive reasoning processes (Vaishnavi, Kuechler and Petter, 2017). In this research study, the tri-composite community of practice, boundary object and knowledge boundary perspective is proposed as a novel approach to guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps. This novel perspective contribution to knowledge is detailed and justified in Chapter 5.

**3.** ***Development of the Artefact***

Once the tentative design solution is clarified, the DSR artefact is designed and developed in line with the research objectives and context (Vaishnavi and Kuechler, 2004; 2008; 2015). Although the development step may involve demonstration, it is possible that a proposed artefact not be implemented in practice, but rather exhibit rigour and relevance through other means of artefact evaluation and refinement (Deng and Ji, 2018). This is permitted with nascent design theory, as in the case of this study's proposed framework (Deng and Ji, 2018). The process of developing an artefact may also be carried out through a series of one or more iterations, which over time, aims to refine and improve the proposed artefact (Hevner and Chatterjee, 2010). The artefact may be developed using deductive or inductive cognitive reasoning (Vaishnavi, Kuechler and Petter, 2017), although this study employs a novel hybrid cognitive reasoning strategy (combining abductive, deductive and top-down inductive cognitive processing). In this research study, one iteration is performed (depicted by the orange and green dashed arrow in Figure 2.5). The preliminary conceptual framework (artefact) is developed in Chapters 6 and 7, and the final revised framework (artefact) is presented in Chapter 10.

**4.** ***Evaluation of the Artefact***

Following its construction, the artefact is evaluated against three pre-determined criteria (Vaishnavi and Kuechler, 2004). The results of the evaluation study provide additional insights and information that feeds back into the artefact's revision and refinement (depicted by the orange and green dashed arrow in Figure 2.5). Artefact evaluation tends to involve deductive reasoning (Vaishnavi, Kuechler and Petter, 2017), although in this study, a hybrid deductive and inductive cognitive reasoning strategy is employed. When evaluating an artefact, a variety of qualitative and/or quantitative methods can be

employed, depending on the study objectives and aims (Vaishnavi and Kuechler, 2015). A handful of DSR evaluation frameworks, such as the FEDS framework (Venable, Pries-Heje and Baskerville, 2016), have been proposed to support and provide credibility to a variety of naturalistic and artificial artefact evaluation methods available for use in DSR projects. In this research study, the conceptual framework is evaluated using a qualitative DSR linguistic interpretivist approach that is introduced, justified and detailed in Chapter 8. Within this approach, one-on-one virtual semi-structured interviews are employed as a data collection method for evaluating the conceptual framework with "outsiders" (Jabareen, 2009, p.54). Although the DSR project as a whole is grounded in pragmatism, the evaluation study falls within interpretivism (depicted in Figure 2.5); two paradigms that can be fused in DSR projects (as discussed in Subsection 2.2.1) (Deng and Ji, 2018). The details and results of the empirical study are presented in Chapter 9. In Chapter 10, the proposed conceptual framework (Chapter 7) and empirical study findings (Chapter 9) are compared in terms of the three evaluation criteria, which informs the refinement and improvement of the final revised framework artefact (illustrated by the iteration cycle in Figure 2.5).

**5.** ***Conclusion of the Research***

The conclusion step represents the finale of a research effort and aims to communicate the findings and output(s) of a DSR research project, in which the results offer a "satisficing… good enough" contribution (Vaishnavi, Kuechler and Petter, 2017, p.10). As discussed in Subsection 2.3.1 and illustrated in Figure 2.4, this DSR project contributes knowledge that is positioned within the "improvement" quadrant (Gregor and Hevner, 2013, p.345). The conclusion stage involves consolidating and writing up the DSR project, and clarifying knowledge gained from the effort as either "firm" (that is, knowledge that can be applied and used) or as "loose ends" (that is, knowledge areas that require further future research) (Vaishnavi, Kuechler and Petter, 2017, p.10). The conclusion incorporates reflection and abstraction as cognitive processes (Vaishnavi, Kuechler and Petter, 2017). The DSR project is concluded in Chapter 11, where the research questions and research objective are revisited, and the artefact (framework) and design knowledge contribution is summarised.

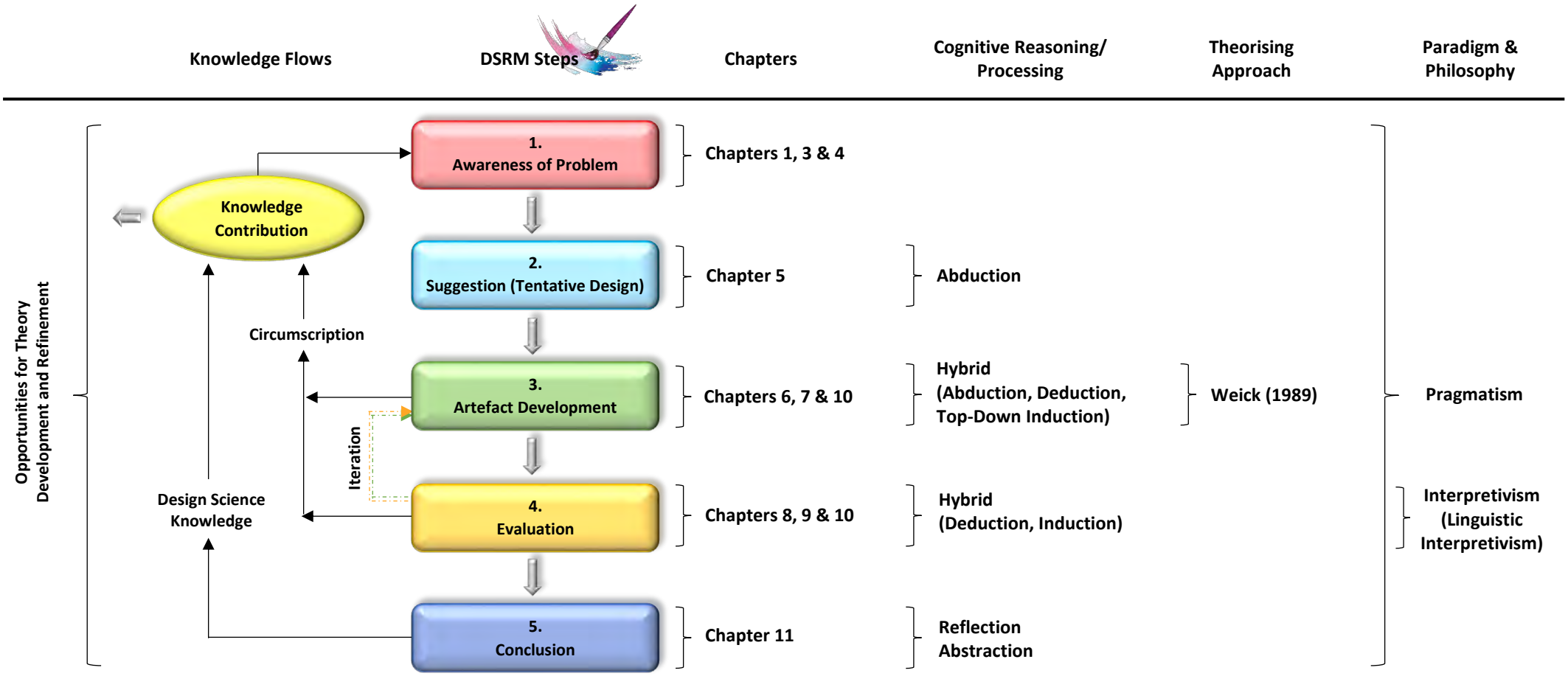



*Figure 2. 5: The Design Science Research Methodology (DSRM) Applied in this Research Study*
*[Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

As illustrated by the arrows in Figure 2.5, circumscription knowledge flows between Steps 3 (development), 4 (evaluation) and 1 (problem awareness) and design knowledge flows between Steps 5 (conclusion) and 1 (problem awareness) (Vaishnavi and Kuechler, 2004; 2008; 2015; Vaishnavi, Kuechler and Petter, 2017). Circumscription is a logical method that assumes every fragment of knowledge is valid only in certain situations, and refers to the discovery of constraint knowledge about theories, which is gained through the detection and analysis of contradictions when things to do not work according to theory (Vaishnavi, Kuechler and Petter, 2017). In other words, the findings analysed from the empirical evaluation study (conducted in Chapter 9) flows back into the DSR artefact development process (as an iteration), and essentially validates the relevance of the theoretical design knowledge in terms of context and practice. Vaishnavi, Kuechler and Petter (2017, p.12) emphasise that circumscription often happens in research, and is not necessarily due to the researcher's misunderstanding of theory, but is rather due to the "incomplete nature of *any* knowledge base". Furthermore, throughout Steps 1 to 5, there are opportunities for the researcher to theorise; that is, to develop and refine theory (as illustrated in Figure 2.5). In good quality DSR, it is necessary that the researcher explicitly detail the cognitive reasoning strategy and theorising approach applied when developing and refining theoretical contributions (Vaishnavi, Kuechler and Petter, 2017).

### 2.3.3 Cognitive Reasoning and Theorising Within Design Science Research

#### 2.3.3.2 Suggestion and Evaluation: Abduction and Hybrid Deduction-Induction

In terms of the proposed artefact suggestion (Step 2, Figure 2.5), abductive cognitive reasoning is used to present the boundary object view (tri-composite theoretical framework) as a novel tentative design solution for addressing the paucity of multi- and interdisciplinary approaches. With regard to the artefact's evaluation (Step 4, Figure 2.5), a hybrid deductive and inductive cognitive reasoning strategy is employed. Deduction informs the empirical data instrument's composition and the theory-driven coding framework for evaluating the proposed framework's components. Induction allows the evaluation empirical interview data to "speak to the theorist [researcher]" through gists that focuses their attention to detect any theoretical-contextual tensions and resolutions (Shepherd and Sutcliffe, 2011, p.368). The nature of abduction, deduction and induction is described further in the following subsection, and the use of an abductive cognitive reasoning strategy and a hybrid cognitive deductive and inductive reasoning strategy are described in more detail in Chapters 5 (Step 2, Figure 2.5) and 8 (Step 4, Figure 2.5), respectively.

#### 2.3.3.2 Artefact Development: A Hybrid Cognitive Reasoning Strategy

When conducting the critical theoretical analysis in Chapter 6 (Step 3, Figure 2.5) and conceptualising, developing and revising the framework (artefact) in Chapters 7 and 10 (Step 3, Figure 2.5), a novel hybrid cognitive reasoning/processing strategy that combines abduction, deduction and top-down induction is employed. Abductive and top-down inductive cognitive reasoning, in particular, are grounded in pragmatism (Peirce, et al., 1934; Shepherd and Sutcliffe, 2011), thus aligning with the philosophical assumptions of this DSR study. A "hybrid" cognitive reasoning strategy, described as comprising two or three reasoning processes, is useful for leveraging the strengths and mitigating the weaknesses of each strategy, whilst remaining open-minded to the creative and innovative thought processing typically required for addressing wicked design problems (Fereday and Muir-Cochraine, 2006, p.83; Gregory and Muntermann, 2011, p.14; Braun and Clarke, 2012; Swain, 2018, p.7).

Firstly, *abductive* reasoning is essential to the design knowledge generation process because it allows a design science researcher to propose a "satisficing explanation" (Lee, Pries-Heje and Baskerville, 2011, p.4) that draws an "inference to the best explanation" (Harman, 1965, p.88). Charles Peirce describes abductive reasoning as "the process of forming ... [a] logical operation which introduces any new idea" and which "suggests that something *may* be" possible (Peirce, 1934, p.171). Through abductive reasoning, a tentative argument or "plausible belief" (Walton, 2008, p.161) is conceptualised through a researcher's "instinctive theory of reasoning" (Peirce, 1932, p.3) guided by their "guessing instinct" (Gold, et al., 2011, p.237). The researcher's intuitive and tacit knowing of a tentative design solution suggestion is driven by the researcher's "association by interest" (Peirce, 1958, p.499) which largely involves speculation, imagination and creative conceptualisation (Gold, et al., 2011). The researcher's suggestion is motivated by an innate "act of insight" (Peirce, 1934, p.181) that, despite being open to fallibility (Josephson and Josephson, 1996), allows the researcher to apply cognitive activities for drawing out subconscious (Swedberg, 2016) and perceptual judgements, thereby translating and materialising their intuitive, tentative and plausible speculation into a conscious explanation and explicitly justified design solution (Magnani, 2005; Paavola, 2006). Essentially, abductive cognitive reasoning and creativity "plays an important role… in the construction" of the study's proposed framework (artefact) contribution (Alturki and Gable, 2014, p.136).

Abductive reasoning is also fitting for this study because its creative and recursive nature allows for the artefact's iterative development and refinement (Mueller and Urbach, 2017) (iteration cycle, Figure 2.5), and its proposed contribution requires satisficing and satisfactory, rather than absolute or true, solutions (Rittel and Webber, 1973; Magnani, 2002). Moreover, when abductive reasoning is used in conjunction with deductive and inductive reasoning, it aids the researcher's cognitive trial-and-error "internal falsification" experiments, and guides the analytical narrowing, scoping, refining and clustering of an emerging design artefact solution and design knowledge contribution (Step 3, Figure 2.5) (Timmermans and Tavory, 2012, p.180).

Secondly, along with abductive reasoning, *deductive* cognitive reasoning is employed so that the researcher can utilise and draw from existing theories and theoretical frameworks (kernel theories) when framing the criteria for constructing the framework (artefact) (Alturki and Gable, 2014). This top-down approach is predominantly evident in the researcher's tri-composite theoretical framework (comprising community of practice, boundary object and knowledge boundary theory; in short, a boundary object view), which is proposed as a novel perspective for addressing the design problem (presented and detailed in Chapter 5, Step 2, Figure 2.5). On the one hand, the theoretical framework is informed by the researcher's 'speculative guess' for what 'may be' a 'satisficing design solution'. On the other hand, the theoretical framework informs the creation of a template (Crabtree and Miller, 1992) which is used to critically review, analyse and draw from existing multi- and interdisciplinary digital health intervention development approaches (Chapter 6, Step 3, Figure 2.5); the findings of which are used to inform the conceptual framework artefact's development (Chapter 7, Step 3, Figure 2.5). Deductive reasoning offers a strength in that it is "diagrammatic" (Campbell, 2011, p.47), meaning it provides a visually-conceivable thought process in which particular conclusions can be logically drawn from one or more general principles (Tsang and Williams, 2012). It also means that based on the researcher's focus of attention (honed by the proposed tri-composite theoretical framework), the conceptual and final revised framework (artefact) and partial (nascent) design theory can be developed through deducing, refining and augmenting one or more general theories (Campbell, 2011).

A purely deductive reasoning strategy is noticeably avoided because, as a cognitive process, it lacks discovery, search and creative intuition, and as a result, does not lead to the generation of new design ideas, theory or knowledge (Fischer, Gregor and Aier, 2012). Whereas, when

combined with abductive reasoning, deductive thought processing allows artefact solution and knowledge contribution to draw from existing process kernel theories (that is, community of practice, boundary object and knowledge boundary theory) and existing product kernel theories or extant artefacts (that is, existing multi- and interdisciplinary digital health intervention development approaches) (Beck, Weber and Gregory, 2013; Alturki and Gable, 2014; Vaishnavi, Kuechler and Petter, 2017). Both types of kernel theories provide justificatory knowledge and credibility when generating new information systems design knowledge (knowledge flows, Figure 2.5) and when developing a novel design artefact solution (Gregor and Jones, 2007; Vaishnavi, Kuechler and Petter, 2017). A purely deductive reasoning process is also avoided because it essentially limits the researcher to a "conceptual tunnel vision" (Morse and Mitcham, 2002, p.30), where there stands the risk that the tri-composite lens-based template (Crabtree and Miller, 1992) functions like blinders. This would lead the researcher to conceptually narrow their focus on certain data, at the cost of excluding other relevant contextual data findings (Guest, MacQueen and Namey, 2012). This risk for conceptual tunnel vision is mitigated by incorporating a partial aspect of inductive reasoning in the hybrid cognitive reasoning strategy.

Therefore, thirdly, together with abductive and deductive reasoning, data-driven *inductive* reasoning is incorporated into the hybrid reasoning strategy. *Bottom-up induction* is well-recognised and frequently applied in information systems DSR studies; with its reasoning process typically understood as inducing inferences from primary empirical data collected during fieldwork (such as interviews and focus groups) (Lee and Baskerville, 2003). *Top-down induction* (Step 3, Figure 2.5) is a more recent, alternative approach (grounded in pragmatism) in which data contained in extant literature or existing frameworks, theories, models or constructs is analysed and the findings induced (Shepherd and Sutcliffe, 2011). Top-down inductive cognitive reasoning allows the researcher to analyse and induce theory from secondary (rather than primary) data as a means to achieving higher levels of (nascent) abstraction and advancing conceptualisation in an information systems DSR study (Beck, Weber and Gregory, 2013). Reviewing and analysing extant literature and existing multi- and interdisciplinary digital health intervention development approaches offers a strength in that instead of trying to 'reinvent the wheel' when developing the conceptual framework (artefact), already proposed and verified concepts, components and categories can be leveraged and extracted to enrich the process of further exploring and creating (newly defined) themes, components and categories (Shepherd and Sutcliffe, 2011; Beck, Weber and Gregory, 2013).

The holistic CEM (customer experience management) framework (Du Plessis and de Vries, 2016) is an example of a DSR study which used a top-down inductive theorising strategy for reviewing, analysing and categorising components from a selected sample of literature (that is, twenty-three existing models, approaches and frameworks), and from which the findings led to the identification of nine themes used to inform the construction of a proposed design artefact (framework). The artefact development process in this DSR research project (particularly Step 3, Chapters 6 and 7) follows a similar approach.

Top-down induction, in comparison to pure deduction (which uses existing theory to strictly frame the researcher's focus from the outset of the analysis) and pure induction (which uses little to no theory, and can easily leave the researcher feeling overwhelmed by the sheer volume of data and possible concept-relationship findings), aims to strike a balance between these two extremes. In addition, top-down induction insists on the incorporation of abductive thinking throughout the reasoning process. Given the mix of reasoning strategies, Shepherd and Sutcliffe (2011, p.375) go as far as to refer to the top-down induction theorising strategy as a "hybrid" process in and of itself. Moreover, in top-down induction, while the researcher is permitted to begin the analysis with a preliminary tentative idea or a plausible explanation (abductive thinking), it still insists that the researcher maintain an open mind by letting the data "speak to" them (Shepherd and Sutcliffe, 2011, p.368).

As the extant literature or selected existing approaches/theories are analysed over time, constant and iterative cognitive cycles comparing sensory and conceptual representations gradually direct and shape the researcher's attention focus by developing "gists" (Shepherd and Sutcliffe, 2011, p.368), ultimately leading to the formation of new theory. Gists can be described as cognitively-generated gestalt-like, holistic representations of the data (or literature) that direct the researcher's focus of attention to specific aspects of the literature, and that direct their focus of attention in discovering and detecting problem tensions (such as conflicts and contradictions) and resolutions (such as solution explanations, similarities, overlaps, constructs and relationships) (Shepherd and Sutcliffe, 2011). Top-down induction offers a dynamic cognitive processing activity similar to that of Weick's (1989, p.516) theorising approach (included in Figure 2.5), which offers a form of "disciplined imagination" in which trail-and-error thought experiments (thought trails) and deliberate diversity can be used to focus the researcher's attention when comparing sensory and conceptual representations (Shepherd and Sutcliffe, 2011), leading to iterative and progressive adjustments

and refinements as greater coherence between the two representations is achieved. Top-down induction is also consistent with the principles of Weick's (1989) theorising approach in terms of creativity, speculative thought and conceptual mapping; that is, using representations to gradually solve a puzzle as more and more pieces are put into place (Shepherd and Sutcliffe, 2011). For the reasons discussed here, top-down induction is deemed an appropriate cognitive thought process to incorporate in the hybrid reasoning strategy.

Overall, the novel hybrid cognitive reasoning strategy is applied when conducting the critical thematic and comparative theoretical analysis in Chapter 6, and when conceptualising, developing and revising the framework (artefact) in Chapters 7 and 10. When performing the critical theoretical analysis, heavier weighting is given to deductive reasoning as the leading theorising strategy, followed by abductive and inductive reasoning, respectively. Figure 2.5 does not depict this weighting order, but rather the order of theorising strategies discussed in this section. On another note, the use of these three reasoning strategies is neither linear nor sequential, but instead occurs concurrently and recursively throughout the framework's iterative development and refinement. Moreover, when conducting the critical analysis, the hybrid cognitive reasoning strategy is nested within Weick's (1989) theorising approach.

#### 2.3.3.2 Theorising Approach

This study adopts and applies Weick's (1989) critical theorising approach to conduct the critical thematic and comparative theoretical analysis performed in Chapter 6 (Step 3, Figure 2.5). Weick's (1989) theorising process consists of three components: (1) *problem formulation*; (2) *thought trials*; and (3) *selection criteria*. These components operate concurrently and iteratively throughout the critical theoretical analysis performed in Chapter 6; behaving similarly to the cognitive and creative thought processes encapsulated within these components (Lee, Pries-Heje and Baskerville, 2011). Weick's (1989) theorising approach has been successfully applied in other information systems doctoral DSR studies and critical theoretical analyses (for example, Mthoko, 2016; Osah, 2017; Baduza, 2020). The particulars of Weick's (1989) theorising approach applied in this study, and particularly the critical theoretical analysis, are further discussed and detailed in Chapter 6.

### 2.3.4 The Design Science Research Cycles

Design Science Research (DSR) cycles should form part of "high quality" research in information systems DSR projects (Hevner, 2007, p.87). Figure 2.6 demonstrates the three

DSR cycles applied within this research project, namely (1) *the relevance cycle*; (2) *the rigour cycle*; and (3) *the design cycle*. In information systems DSR projects, there needs to be evidence that: (1) the proposed artefact (framework) is both addressing a relevant real world problem, and providing a relevant design artefact solution, in terms of a specific context and application environment; (2) the proposed artefact is both grounded in and informed by appropriate (kernel) theories, methods and artefacts existing in the knowledge base, and contributes novel additions to the knowledge base; and (3) the proposed artefact is iteratively built/developed, evaluated, justified and refined over time (that is, where design activities constitute the core of any DSR project) (Hevner, 2007; Hevner and Chatterjee, 2010). The hybrid cognitive reasoning strategy and Weick's (1989) theorising approach are incorporated in both the rigour cycle and the design cycle. The process of critically reviewing and analysing appropriate (kernel) theories and existing multi- and interdisciplinary digital health intervention development approaches to inform the proposed framework's (artefact's) development also takes place within the two rigour and design cycles. The framework (artefact) then undergoes an assess/refine iteration when evaluated and improved through virtual semi-structured interviews with knowledgeable researchers and industry practitioners, thus demonstrating its relevance and credibility to the application context and environment (relevance cycle). The final DSR project artefact and design knowledge contributes to the existing knowledge base and environment on the interdisciplinary design, development and evaluation of mHealth physical activity behaviour change intervention apps.

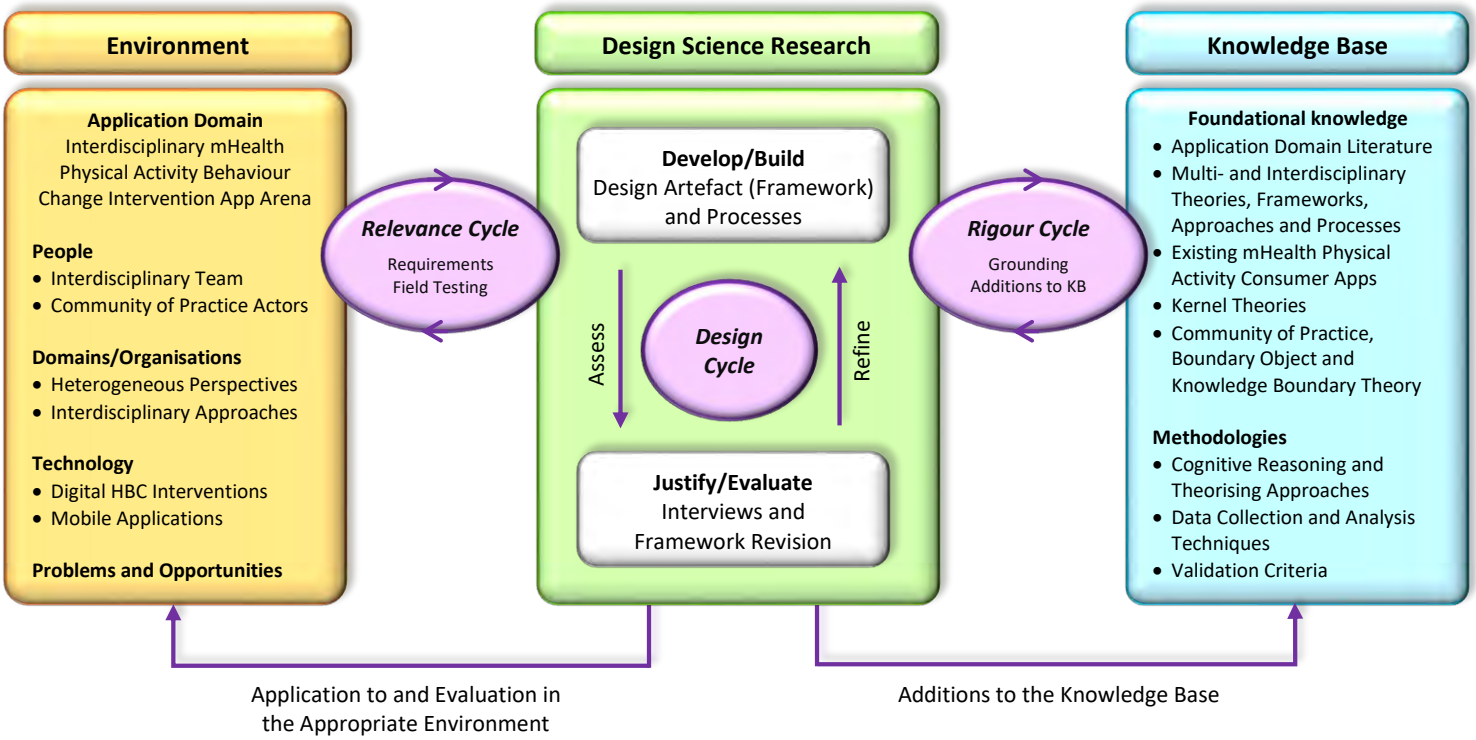





*Figure 2. 6: The Three Design Science Research Cycles [Source: Adapted from Hevner (2007)]*

#### 2.3.4.1 The Relevance Cycle

The relevance cycle initiates when a practical, real world problem is identified in the environment, and drives the DSR process in an attempt to address the problem with a novel design artefact idea (suggested tentative design) (Hevner, 2007). The environment represents the application domain in which the built artefact can be tested and verified (Hevner, 2007). The environment is made up of the people, domain(s)/organisation(s), technology, problems and opportunities relevant to a particular research problem (depicted in Figure 2.6) (Hevner, 2007). The application domain also informs the evaluation criteria used for assessing and verifying the framework (artefact) (Hevner and Chatterjee, 2010). The results and findings from the artefact evaluation study in the application domain (Chapters 8 and 9) informs the initial conceptual framework's (Chapter 7) further iterative refinement (Chapter 10), particularly in terms of the mobile health physical activity behaviour change intervention consumer app context/environment. The results and findings from the primary empirical study performed with knowledgeable academic researchers and commercial industry practitioners, who have real world experience as project managers, team leaders and general team members of multi- and interdisciplinary collaborative mHealth physical activity behaviour change intervention app projects, further evidences the relevancy of the problem and framework (artefact) solution.

#### 2.3.4.2 The Rigour Cycle

The rigour cycle ensures that the DSR project is grounded in and informed by relevant scientific theories and methods, kernel theories and additional knowledge from the extant knowledge base (Hevner, 2007; Vaishnavi, Kuechler and Petter, 2017). According to Hevner (2007), additional knowledge includes experiences and expertise (which define the state-of-the-art in the application domain/environment), and existing artefacts and processes (which are knowledge contributions and meta-artefacts found in the application domain/environment). The rigour cycle also ensures that innovation is indeed taking place in the information systems DSR project (Hevner, 2007), and that the project's knowledge contribution does not fall within the routine design quadrant (see Figure 2.4). The researcher's selection, adaption and application of appropriate theories and methods for developing and evaluating the framework (artefact) determines the rigour in a DSR project (Hevner, 2007). Furthermore, DSR adds to the existing knowledge base through the extension of existing theories and methods, the design and development of novel artefacts, and the experiences gained from the implementation and

evaluation of a proposed artefact in the application domain/environment (Hevner, 2007). In this research study, the rigour cycle provides: (1) appropriate theories on community of practice actors, boundary objects and knowledge boundaries (Chapter 5); (2) relevant theories and additional knowledge on multi- and interdisciplinary collaborative team design, development and evaluation in mHealth physical activity behaviour change intervention app projects, found through the literature review (Chapters 3 and 4) and the critical theoretical analysis (Chapter 6); and (3) appropriate methodologies, methods and techniques for constructing, theorising and evaluating the framework, and conducting the DSRM steps (Figure 2.5).

#### 2.3.4.3 The Design Cycle

The core of any DSR project and methodological process is the design cycle, which represents the key "develop/build" and "justify/evaluate" activities performed during the iterative development, evaluation and refinement of a proposed artefact (Hevner, et al., 2004, p.80; Hevner, 2007). Within the design cycle, design activities iterate more rapidly between the construction of the framework (artefact), its evaluation, and subsequent (primary empirical study) feedback to refine the design solution further (Hevner, 2007). The framework artefact's construction and evaluation is based on relevance and rigour. The design cycle is independent in its execution processes (Steps 3 and 4 in Figure 2.5, corresponding to "develop/build" and "justify/evaluate" in Figure 2.6, respectively); yet, also maintains a dependency on both the relevance and rigour cycles since the application domain and knowledge base are essential informants for the artefact's initial construction and iterative refinement and revision (Hevner, 2007). The requirements for evaluating the artefact are drawn from the relevance cycle, while the knowledge necessary for designing and evaluating the artefact are drawn from the rigour cycle (Hevner, 2007). In this research study, the design cycle involves the construction and evaluation of a framework for guiding and supporting interdisciplinary teams in the collaborative design, development and evaluation of mHealth consumer apps for physical activity behaviour change. Within the design cycle activities, the hybrid cognitive reasoning strategy and Weick's (1989) theorising approach are employed as guiding tools towards constructing the proposed framework (DSR artefact contribution).

## 2.4 The Evaluation of a Design Science Research Project

Evaluating the quality of a DSR project and its research design (structure) is necessary to verify and evidence its credibility and demonstrate the trustworthiness of its methodological process, result findings, design knowledge contribution and design science artefact contribution

(Hevner, et al., 2004; Gregor and Hevner, 2013). A good quality research design demonstrates design coherence and design validity (Saunders, Lewis and Thornhill, 2016). This means that the research design is coherent (fit-for-purpose; employing appropriate methodological tools, methods and techniques to answer the research questions and achieve the research objectives within the chosen paradigm) and valid (internal and external validity of the conclusions) (Saunders, Lewis and Thornhill, 2016). Referencing and adhering to DSR guidelines (Hevner, et al., 2004) and DSR communication and publication schema (Gregor and Hevner, 2013) can provide evidence for a good quality information systems DSR doctoral research study.

### 2.4.1 Design Science Research Guidelines

Hevner, et al. (2004, p.77) provide a set of seven guidelines for conducting and evaluating "good" quality DSR. The seven guidelines put forward by Hevner et al. (2004) and outlined in Table 2.2 include: (1) *design as an artefact*; (2) *problem relevance*; (3) *design evaluation*; (4) *research contributions*; (5) *research rigour*; (6) *design as a search process*; and (7) *communication of research*. These guidelines are met as the researcher acquires knowledge and understanding of the design problem and its solution throughout the process of building, demonstrating and evaluating the design artefact solution (framework) (Hevner, et al., 2004). In Table 2.2 Hevner, et al.'s (2004) four types of design artefact output contributions that can be produced in DSR studies, namely constructs, methods, models and instantiations, is updated to include Gregor and Jones's (2007) design theory, and three additional artefact types, namely frameworks, architectures and design principles (Vaishnavi, Kuechler and Petter, 2017).

*Table 2. 2: Guidelines for Conducting Design Science Research*
*[Source: Researcher's own construction, informed by Hevner, et al. (2004), Hevner and Chatterjee (2010) and Vaishnavi, Kuechler and Petter (2017)]*

| DSR Guideline | Application of DSR Guideline to Artefact (Framework) Design |
|---|---|
| **Guideline 1: Design as an Artefact**<br><br>DSR should produce a viable artefact in the form of a construct, method, model, instantiation, design theory, framework, architecture or design principles. | • A framework for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps is developed. In short, referred to as the "Interdisciplinary mHealth App Design Framework".<br>• The framework highlights relevant and useful boundary objects and supporting artefacts and knowledge boundary sharing practices that heterogeneous community of practice actors can employ and apply when collaboratively designing, developing and evaluating physical activity consumer apps in any given interdisciplinary mHealth behaviour change intervention app project. |
| **Guideline 2: Problem Relevance** | • Digital behaviour change interventions, and mHealth physical activity consumer apps in particular, have gained increasing interest in recent years. |

| | |
|---|---|
| DSR should produce technology-based solutions that aim to address relevant and practical, real world problems. | • There are, however, several key challenges regarding the design of mHealth (physical activity) behaviour change intervention apps, and the root problem lies in the paucity of multi- and interdisciplinary approaches for guiding and supporting project teams during the collaborative design, development and evaluation process<br>• By using and creating various boundary objects and supporting artefact, and engaging in knowledge sharing practices, actors from multiple diverse, yet relevant, communities of practice can meaningfully collaborate as an interdisciplinary team when carrying out successful mHealth intervention app projects. |
| **Guideline 3: Design Evaluation**<br><br>The utility, quality and trustworthiness of a design artefact should be demonstrated using well-executed evaluation methods. | • Evaluation approach: The proposed framework is evaluated using a qualitative DSR linguistic interpretivist approach, involving an interpersonal verification process.<br>• Evaluation data collection method: Qualitative one-on-one virtual semi-structured interviews (snowball sampling technique).<br>• Evaluation data analysis method: A qualitative thematic analysis incorporating a hybrid deductive and inductive cognitive reasoning strategy.<br>• Evaluation criteria: (1) construction adequacy; (2) language adequacy; and (3) clarity.<br>• The framework is evaluated by conducting interviews with knowledgeable and experienced experts and practitioners in both academia/research and industry/commercial practice. The interviews aim to interpersonally verify, modify and further contextualise the main components of the framework. The interview focuses on the physical activity and mobile app contexts. The interview findings inform the framework's iterative refinement and revision. |
| **Guideline 4: Research Contributions**<br><br>DSR should provide clear and verifiable contributions in the areas of the design artefact itself, design foundations and/or design methodologies. | • The Interdisciplinary mHealth App Design Framework is the primary artefact contribution, which aims to provide guidance and support to interdisciplinary project teams during the process of collaboratively designing, developing and evaluating mHealth (physical activity) behaviour change intervention consumer apps. The framework proposes a novel tri-composite (community of practice, boundary object and knowledge boundary) solution perspective to addressing the defined research problem.<br>• Four theoretical contributions are made to the mHealth intervention app design body of knowledge, particularly in terms of existing multi/interdisciplinary digital health intervention development approaches, key design challenges, boundary object view themes and subthemes, and key challenges and opportunities for future improvement.<br>• Practical contributions are made in the form of guideline recommendations for practice and a reasoned and demonstrated proof of concept.<br>• Methodological contributions are made to DSR construction and evaluation knowledge, in the form of the overall research process, a novel tri-composite theoretical framework, a novel hybrid (abductive, deductive and top-down inductive) cognitive reasoning strategy, the application of a qualitative DSR linguistic interpretivist approach, and the adoption of three evaluation criteria which have not yet been utilised in DSR studies. |
| **Guideline 5: Research Rigour**<br><br>DSR should apply rigorous methods during the construction and evaluation of a design artefact. | • Weick's (1989) theorising approach is used in conjunction with a hybrid cognitive reasoning strategy to conduct a critical thematic and comparative theoretical analysis on twenty existing multi/interdisciplinary approaches (as a secondary dataset) categorised across four perspectives. The findings of the critical theoretical analysis informs the conceptual framework's construction, which together with reviewed literature, demonstrates rigour with the knowledge base (illustrated in Figure 2.6).<br>• The initial proposed conceptual framework is rigorously evaluated in a primary empirical study with knowledgeable and experienced experts and practitioners in the environment/application domain, yielding feedback that informs the interpersonal verification, modification, contextualisation and revision of the enhanced framework. |
| **Guideline 6: Design as a Search Process**<br><br>The search for a satisficing design artefact utilises available means to reach desired ends while satisfying laws in the problem environment. | • The artefact design solution draws from twenty existing multi- and interdisciplinary digital health intervention development approaches that inform the proposed conceptual framework's development.<br>• The framework evaluation and interpersonal verification process performed with knowledgeable and experienced academics/researchers and industry practitioners ensures the relevance of the framework to the environment/application domain, informs modifications to the framework's domain ontology, and provides additional contextual insights that inform the iterative refinement and revision of the enhanced Interdisciplinary mHealth App Design Framework as a design artefact solution. |

| | |
|---|---|
| **Guideline 7: Communication of Research**<br><br>DSR should be presented clearly and effectively to technology-orientated and practice-orientated audiences. | • The process applied in developing, evaluating and (iteratively) revising the initial conceptual and enhanced framework is clearly and explicitly described and justified.<br>• The underlying novel tri-composite (community of practice, boundary object and knowledge boundary) theoretical framework solution perspective (to address the defined research problem) is clearly and explicitly described and justified.<br>• The main and supplementary components (and subcomponents) of the initial conceptual and revised enhanced framework are presented and described in detail to clearly and effectively communicate the artefact's quality and trustworthiness.<br>• Publications on this DSR research project aids its communication. |

### 2.4.2 Design Science Research Communication and Publication Schema

While Hevner, et al.'s (2004, p.77) seven guidelines provide guidance for constructing and evaluating "good" quality DSR, Gregor and Hevner (2013, p.349) argue that the guidelines predominantly focus on the development and evaluation of the artefact itself, and places "little emphasis on what it means to make a contribution to generalised knowledge". To address this gap, Gregor and Hevner (2013) provide a communication and publication schema for information systems design science researchers to ensure that the process followed when carrying out their DSR projects is explicitly and effectively communicated. Gregor and Hevner (2013) put forward seven communication and publication schema (outlined in Table 2.3): (1) *introduction*; (2) *literature review*; (3) *method*; (4) *artefact description*; (5) *evaluation*; (6) *discussion*; and (7) *conclusions*. These seven communication and publication schema correspond to the eleven chapters in this information systems DSR project.

*Table 2. 3: Communication and Publication Schema for an Information Systems DSR Project [Source: Adapted from Gregor and Hevner (2013)]*

| Section of DSR Project | Contents of Section |
|---|---|
| **1. Introduction** | The introduction should include: the problem definition; the problem significance and rationale; an introduction to key concepts; research questions and objectives; the aims of the artefact contribution; the study's scope; an overview of the methods and results; and the structure of the DSR project. |
| **2. Literature Review** | The literature review should cover existing and prior work that is relevant to the study, including: key concepts; theories; design theory(ies) and design knowledge relating to the class of problems to be addressed; empirical research studies; findings from the practice environment/application domain; artefacts that have already been developed to solve the same or similar problems (that is, existing multi- and interdisciplinary digital health intervention development approaches); and existing instantiations (that is, real world commercially published and research-based mHealth physical activity consumer apps). |
| **3. Method** | The research design that is employed to carry out the DSR project, including the: paradigm and philosophy; research methodology (DSRM); research approach (DSR); theorising strategy(ies); cognitive reasoning strategy(ies); and the methods and techniques (for primary and secondary data collection and analysis). The research design particulars should be explicitly described and clearly justified. |
| **4. Artefact Description** | A concise description of the proposed artefact (framework) at the appropriate level of abstraction to make a novel contribution to the knowledge base. The artefact's description and the design search process should be detailed and clearly communicated. |

| | |
|---|---|
| **5. Evaluation** | The artefact should be evaluated to provide evidence for its utility, credibility and trustworthiness. The process employed to evaluate the artefact and the evaluation criteria need to clearly described and justified. |
| **6. Discussion** | The discussion provides an interpretation of the results and findings from the critical theoretical analysis and the primary empirical evaluation study. The discussion should cover: what the results are; what the results mean; how the results relate back to the objectives of the critical theoretical analysis and the primary empirical evaluation study. The discussion can also include: a summary of lessons learned; comparisons with prior work; theoretical significance; practical significance; limitations; and areas for further/future research. |
| **7. Conclusions** | The concluding paragraphs should: revisit the research questions and objectives; restate the important findings of the research; restate the main contribution(s); and explain the research and contributions importance. |

## 2.5 Conclusion

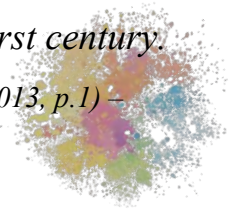
This chapter covered the research structure of this information systems DSR project. Subsequent to the chapter's first section, which provided an introduction, the chapter's second section introduced and discussed the selection of a research paradigm and philosophy (pragmatism, with interpretivism, incorporating symbolic interactionism and sociomaterialism) and a research approach (DSR) in relation to other paradigms and approaches. Thereafter, the chapter's third section discussed the research design, covering: a detailed introduction to and outline of the research approach (DSR); the research methodology (DSRM); the cognitive reasoning strategy (a hybrid abductive, deductive and top-down inductive strategy); the theorising approach (Weick's theorising process); and the three DSR cycles (the relevance, rigour and design cycles). Following this, section four provided a discussion on the evaluation of a DSR project, outlining the seven DSR guidelines and the seven communication and publication DSR schema. Six figures and three tables provided illustrative and tabularised accompaniments with the discussions. Overall, the research design detailed in this chapter covers the process undertaken to answer the main research question and achieve the main research objective.

# Chapter 3

## The Health Landscape: Health Promotion and the Physical Activity Domain

*The global burden and threat of noncommunicable diseases constitutes one of the major challenges for health and development in the twenty-first century.*

*– World Health Organisation (2013, p.1) –*



## 3.1 Introduction

The global pandemic of noncommunicable diseases (NCDs), and its associated premature mortality rates and socioeconomic burden, have led to increasingly intensified efforts towards designing and delivering health promotion interventions aimed at addressing the leading modifiable health risk behaviours, such as physical inactivity and unhealthy eating (Allen, 2017; Bennett, et al., 2020; Budreviciute, et al., 2020; WHO, 2020a). This chapter starts by presenting the global health status on NCDs and its associated death statistics and socioeconomic burden, before introducing modifiable health risk behaviours as the leading causes for NCDs. The following section introduces the field of health promotion and health promotion behaviour change interventions in addressing the global NCD pandemic and their associated modifiable health risk behaviours. The socioecological model for health promotion is presented and justifications are provided for the research study's delineation to the dual intra-interpersonal socioecological levels.

The subsequent section introduces health promotion and health behaviour change interventions in the context of the physical activity domain. This covers the global physical inactivity pandemic, and the role of physical activity – as a leading modifiable health risk behaviour – in fighting NCDs. Further discussions are then provided on the global response to the physical inactivity pandemic and the current global status of health promotion interventions for physical activity behaviour change, including an overview of the World Health Organisation's physical activity guidelines. Thereafter, a section is presented on the design of health promotion behaviour change interventions for physical activity at the dual intra-interpersonal socioecological levels. This section provides an overview of the role of theory, determinants and correlates, and behaviour change techniques in designing effective health promotion behaviour change interventions for physical activity, and closes with a brief overview of the challenges faced in designing such interventions; after which the chapter is concluded.

The main aim of this chapter is to provide insight into the contextual landscape of the research and evidences the relevance and significance of the practical real-world problem. As illustrated in Figure 3.1, gaining an understanding of the problem space falls within Step 1 ("awareness of problem") of the study's DSRM (outlined in Chapter 2). This chapter contributes to answering the first research sub-question: *"What is the role of mobile technology in delivering interventions for promoting physical activity behaviour change?"*.

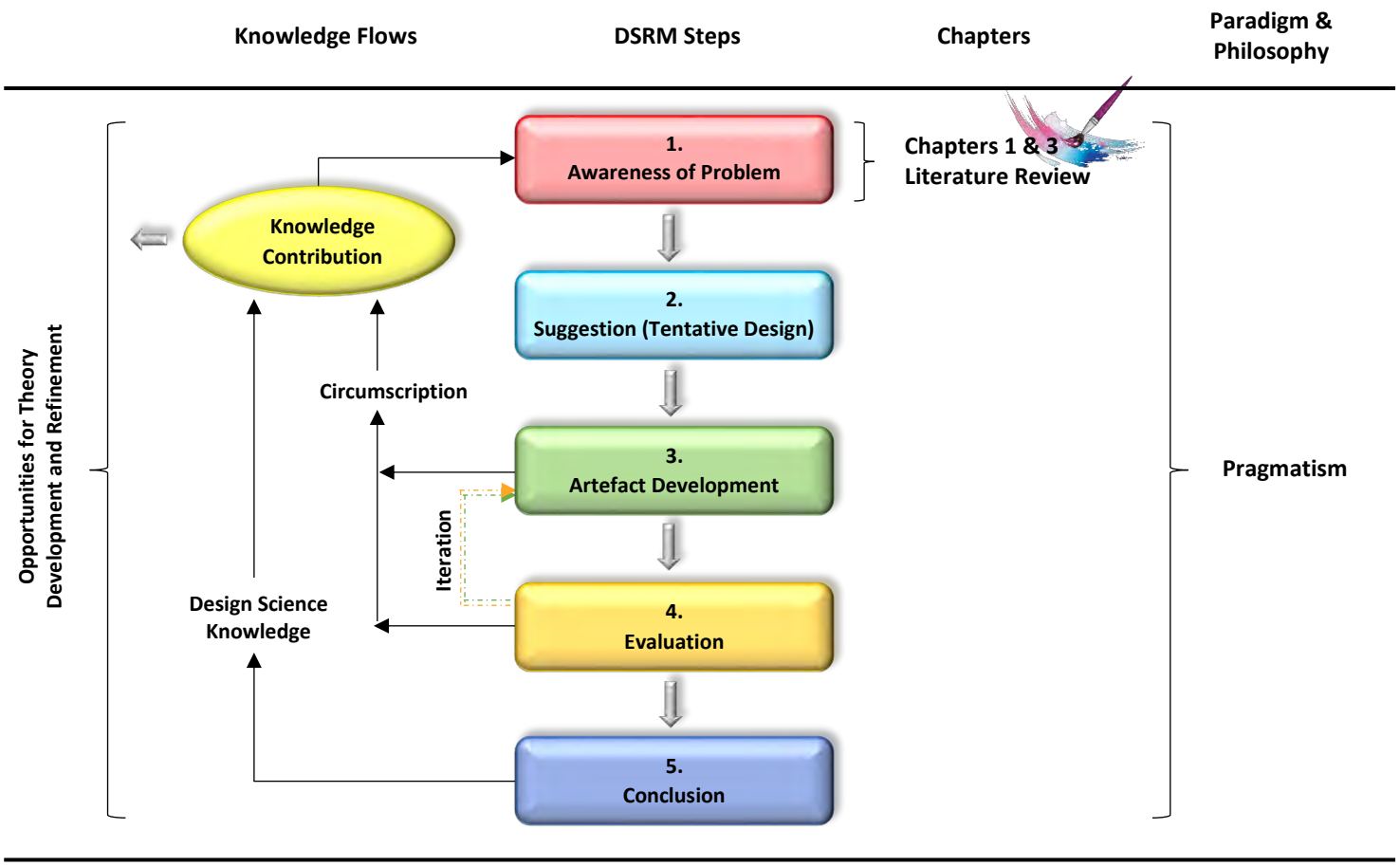



*Figure 3. 1: DSRM: Gaining an Awareness and Understanding of Problem Space [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 3.2 The Global Health Status on Noncommunicable Diseases

Noncommunicable diseases (NCDs) are the world's leading cause of premature mortality – a global plight that places a significant and ever-increasing burden on the health statuses and socioeconomic conditions of countries worldwide (Allen, 2017; Bennett, et al., 2020; Wang and Wang, 2020; WHO, 2020a; 2020b). In 2019, NCDs made up seven of the top ten causes of death globally, an increase from four out of ten in 2000 (WHO, 2020a; 2020b). According to the World Health Organisation (WHO, 2014), the United Nation's leading international public health specialised data analytics and reporting agency, NCDs are non-infectious and non-transmissible chronic medical conditions or diseases that progress gradually and endure for an extended duration of time. The four leading NCDs, namely cardiovascular diseases, cancers, chronic respiratory diseases and diabetes, account for 80% of premature NCD deaths worldwide (WHO, 2021). For a clear distinction, communicable diseases, in contrast, are infectious and transmissible, such as the novel severe acute respiratory syndrome coronavirus 2 (loosely referred to as COVID-19), tuberculosis and human immunodeficiency virus

(Amimo, Lambert and Magit, 2020). In 2018, the WHO reported NCDs as responsible for killing 41 million people each year, which is equivalent to 71% of global deaths (WHO, 2021). In 2019, this equivalent rose to 74% (WHO, 2020b). A significant proportion of these 41 million deaths are described as premature; in other words, every year, around 15 million people die from a NCD or NCD comorbidity between the ages of 30 and 69 years (WHO, 2021). References to total deaths, in comparison, concern mortalities caused by NCDs, communicable diseases, injuries and other sources (WHO, 2014). Global and national calculations of premature mortality offer a valuable measurement that is representative of unfulfilled life expectancy, lost socioeconomic productivity and reduced economic activity and development (WHO, 2014; Wang and Wang, 2020).

The global NCD crisis has reached pandemic proportions, with people across geographical positioning, age grouping and demographical profiling evidenced to be potentially susceptible to NCDs (Allen, 2017; WHO, 2017a). Whilst no country is exempt, WHO analyses reveal low- and middle-income countries as bearing 85% of the annual 15 million NCD-attributed premature deaths (between ages 30 and 69 years) (WHO, 2021). In 2019, the top ten causes of total deaths in low and lower-middle income counties, however, were not only from NCDs, but were also largely attributable to communicable diseases and injury (WHO, 2020b). In contrast, the top nine out of ten causes of total deaths in 2019 in high-income countries were attributable to NCDs (WHO, 2020b). Low and middle-income countries face challenges associated with financial debts and pervasive socioeconomic issues and poverty, with the majority of population groups living with unmet basic needs, inexistent or sub-standard sanitary conditions, no clean water, and insufficient availability of and access to quality healthcare services (in both public and private sectors) (WHO 2014; 2016). Together with the prominent shortage of qualified health professionals and the demands generated by the COVID-19 pandemic, low- and middle-income countries' healthcare systems are significantly ill-equipped, ill-prepared and insufficiently capable of managing and rectifying the health challenges resulting from the increasing NCD pandemic (WHO, 2016; 2017a; 2020d). Nevertheless, despite the disproportionate challenges faced by low- and middle-income countries, years of WHO analyses evidence that NCD-attributable deaths a significant cause for concern across low-, middle- and high-income countries; that is, regardless of socioeconomic status and living conditions (Defo, 2014; World Bank, 1993; WHO, 2000; 2008; 2014; 2020b). Box 3.1 provides additional statistics on the increasing global total and

premature NCD deaths over recent years, figures pertaining to NCD mortalities in low-, middle- and high-income countries, and regional and country-specific NCD death statistics.

Noncommunicable diseases also place a significant direct and indirect financial and economic burden on low-, middle- and high-income countries across the world (Jaspers, et al., 2015; Ding, et al., 2016; Nugent, 2017). According to Bloom, et al. (2011), from 2010 to 2030, a simulated cumulative total output loss of over US$30 trillion will be attributable to the four leading NCDs. Together with mental health costs, this estimated output loss rises to over US$47 trillion over (Bloom, et al., 2011). From 2012 to 2030, the four major NCDs are estimated to cost China and India cumulative output losses of US$18.41 trillion and US$3.87 trillion, respectively (Bloom, et al., 2013). For more financially fragile countries, the exorbitant healthcare costs associated with NCDs quickly drain vulnerable, socially-disadvantaged low-income and low-resource households, ultimately pushing millions of people into impoverishment on an annual basis, further stifling countries' socioeconomic development (Jaspers, et al., 2015; Naik and Kaneda, 2015). Bloom, et al. (2011) further estimate high-income countries as carrying over half of the total global NCD financial burden. While the true monetary value of NCDs is immeasurable, evidence affirms that across all continents and income levels, the far-reaching ramifications and financial consequences imposed on fiscal, monetary, health and household sectors, as well as countries' socio-development and economic growth, is alarming (Bloom, et al., 2011; WHO, 2014; Jaspers, et al., 2015; Ding, et al., 2016; Nugent, 2017; Wang and Wang, 2020).

## Global Deaths Attributable to Non-Communicable Diseases (NCDs)

***Global Total and Premature NCD Deaths***

Statistically, the proportions of deaths attributable to NCDs have increased worldwide over the last 20 years. In 2000, 31.3 million (60%) of the total 52.1 million global deaths were due to NCDs; of which 14.6 million (46%) occurred prematurely. In 2008, of the total 57 million global deaths, 36 million (63%) were due to NCDs, of which an estimated 44% were premature. In 2012, NCD-attributable deaths increased by another five percent to 38 million (68%) of the total 56 million deaths worldwide, of which 16 million (42%) were premature. In 2015, NCDs were responsible for 39.5 million (70%) of the total 56.4 million deaths worldwide, of which nearly half (48%) were premature. In 2018, NCDs caused 71% (41 million) of global total deaths, which again increased to 74% of the global total deaths (55.4 million) in 2019. As for the leading four NCDs, from 2010 to 2017, mortality rates attributed to cardiovascular diseases increased from 16.6 million to 17.9 million, cancers rose from 8.1 million to 9 million, chronic respiratory diseases from 3.6 million to 3.9 million, and deaths from diabetes increased from 1.3 million to 1.6 million.

***NCD Deaths across the WHO's Global Regions***

Millions of people die annually from NCDs across all of the WHO's six global regions, comprising 194 member states. The Region of the Americas (made up of 52 member states) estimated around 4.8 million NCD deaths in 2012, making up 79% of total deaths in the Americas. The Eastern Mediterranean Region (comprising 21 member states and the Palestine territories on the West Bank and Gaza Strip) reported 2.2 million NCD deaths in 2012 (57% of total deaths), of which 51% were premature under the age of 70 years. NCD deaths in the South-East Asia Region (constituting 11 member states) accounted for 8.5 million lives lost (62% of total deaths in the region), of which an estimated 48% of these NCD deaths were premature. The European Region (consisting of 53 member states) 86% of deaths resulted from NCDs, with the four major NCDs and mental health disorders accounting for over 77% of the European Region's disease burden. The Western Pacific Region (constituting 37 member states) reported 10.9 million deaths as attributable to NCDs in 2012, accounting for over 80% of total deaths, of which 50% were people under the age of 70 years. Lastly, in 2012, the African Region (comprising 47 member states) reported nearly 2.8 million NCD-attributable deaths (28.6% of total deaths). In 2015, NCD deaths in the African Region increased to 3.1 million, making up 33.5% of total deaths in the region.

***NCD Deaths across Low-, Middle- and High-Income Countries***

In 2012, low- and middle-income countries bore nearly three quarters – 28 million of the 38 million (74%) – of the world's total NCD deaths, and carried 82% of the world's total premature NCD deaths (under the age of 70 years). Three years later, in 2015, the proportion of the global total NCD deaths carried by low- and middle-income countries increased from 74% to 78% – from 28 million to 30.7 million. Of the 30.7 million NCD deaths in low- and middle-income countries, 48% were premature, before the age of 70 years. This 48% is in sharp contrast to high-income countries, whose premature NCD deaths approximate between 26-28%.

***Projected NCD Deaths***

The world's total NCD-attributable deaths are projected to increase from 39.5 million in 2015 to 52 million in 2030. In the African Region, for instance, NCDs are projected to cause an estimated 3.9 million deaths by 2020, which shows a gradual increase from the 3.1 million and 2.8 million deaths in 2015 and 2012, respectively. NCDs in the African Region are projected to increase by 27% over the next 10 years, while other world regions are projected to increase by 17%.

*Box 3. 1: Global Deaths Attributable to Non-Communicable Diseases (NCDs) [Source: Researcher's own construction, informed by WHO (2000; 2008; 2010a; 2014; 2017a; 2020a; 2020b; 2021)]*

In addressing NCDs, the development and implementation of global and national health intervention strategies and policies can be costly. However, given the presented evidence and current global health climate with the NCD pandemic, it would be "... illogical and irresponsible..." for economic policy makers to sideline the ever-growing NCD-related concerns and ever-cumulating cost effects (Bloom, et al., 2011, p.37). Without effective intervention and evidence-based action, the WHO projects that in 2030, NCDs will kill 52 million people (WHO, 2014). Together with a consideration for the evidence-based health, socioeconomic and financial consequences of NCDs and its associated mortality rates, the insufficient action and failures to effectively implement sustainable health interventions and policies present significant and undeniable (monetary and nonmonetary) costs for countries worldwide, regardless of income standing (Bloom, et al., 2011; Jaspers, et al., 2015; Nugent, 2017; WHO, 2017a). Furthermore, addressing NCDs and their associated death rates requires an understanding of their aetiology. Insight into NCD aetiology and its associated contributing factors informs and aids efforts to reduce and prevent their development and progression (WHO, 2014). Noncommunicable diseases, unlike communicable diseases, do not have a single infectant identifier; they are instead caused by lifestyle behaviours that can be positively modified and changed, thereby reducing and preventing the chances of NCD development and progression over time (WHO, 2014; 2017a).

Leading modifiable health risk behavioural factors contributing to all NCDs, and the four leading NCDs in particular, include physical inactivity, unhealthy dietary intake, tobacco use and harmful alcohol consumption (WHO, 2010a; 2021). These four key predisposing modifiable risk behaviours affect physiological and metabolic changes in the human body, primarily through hyperglycemia (raised blood glucose levels), hyperlipidemia (increased cholesterol levels), hypertension (high blood pressure), and unhealthy weight gain (being clinically overweight or obese) (WHO, 2014; 2015). To clarify, the term 'health (risk) behaviour' refers to an individual's overt behavioural patterns, choices, actions and lifestyle habits that, regardless of their current health status, can positively (or negatively) influence or maintain, improve and restore (or degenerate) one's health (Whitehead, Dahlgren and Gilson, 2001; Conner and Norman, 2017). Substantial volumes of epidemiological literature and evidence-based studies have consistently demonstrated associations between the key contributing health risk behaviours – insufficient physical activity and obesity (Lee, et al., 2012; Rhodes, et al., 2017; Uddin, et al., 2020); unhealthy diet (De Ridder, et al., 2017); tobacco use (West, 2017); and harmful alcohol consumption (Parry, Patra and Rehm, 2011) –

and their long-term effects on ill health, NCDs and premature mortality (WHO, 2010a; 2014). When left unmanaged, these key lifestyle behaviours can all feed the development of NCDs and NCD comorbidities (WHO, 2010a, 2017a). Habitually performing risky health risk behaviours involves processes of conscious choice and intentional action, essentially deeming them "lifestyle diseases" (Tabish, 2017, p.1; Stoeva, 2020, p.2). These risky health behaviours are, however, modifiable and can be actively adjusted and changed through patterns of habitual conscious decision-making and deliberate action execution in daily living (WHO, 2014; Uddin, et al., 2020). Notably though, not all lifestyle decisions, and hence the risk of NCDs, are solely influenced by individuals' health risk behaviours, considering that NCDs can also develop as a result of factors relating to genetics (that is, hereditary), aging, physiology, socioeconomic conditions and the environment (such as rapid urbanisation) (Egger and Dixon, 2014; WHO, 2014). Nevertheless, the key important point is that many NCD-attributable (premature) deaths are preventable, and that conscious and active efforts towards improving predisposing health behaviours and lifestyle patterns – by engaging in sufficient physical activity, eating healthier, limiting (or stopping) alcohol consumption, and eliminating tobacco use – can proportionately decrease the risks of NCD or NCD comorbid cluster development (WHO, 2010a; 2014; Tabish, 2017; Stoeva, 2020).

In global efforts to reduce the prevalence of NCDs and the role modifiable health risk behaviours play in their development, and to alleviate their associated financial cost burden socioeconomic consequences, premature (and total) death rates and increasingly strained (public and private) healthcare systems, institutions such as the WHO and United Nations (UN) have poured significant resources into the development and implementation of health strategies, policies and interventions. The WHO's *Global Action Plan for the Prevention and Control of NCDs 2013-2020* (WHO, 2013) and the United Nation's (UN) *2030 Agenda for Sustainable Development* (UN, 2015), for example, incorporate road maps of policy options and goals for countries to focus efforts towards the promotion of modifiable health risk behaviours and the reduction of NCDs. The WHO's global action plan for NCDs (WHO, 2013) includes seven (of nine) targets for physical inactivity, unhealthy diet, high sodium intake, obesity, high blood pressure, harmful alcohol consumption and NCD-attributable premature mortality. The UN's 2030 Agenda for Sustainable Development (UN, 2015) incorporates the "ambitious" (Nugent, 2017, p.I) goal (SDG target 3.4) to reduce premature NCD-attributable deaths by one third by 2030. These reports, in addition to a range of other NCD policy strategies and interventions across global (WHO, 2010a; 2014; 2017a; WHO, 2017b), regional (WHO,

2015) and national (Ministry of Health Rwanda, 2015) spheres, reflects the importance placed on global efforts towards the promotion of healthier lifestyles and reduction of NCDs and premature mortalities.

In essence, the global health status on NCDs represent "one of the major health and development challenges of the 21st century", especially in terms of the prominent human suffering and long-term harm they bring to the socioeconomic fabric of global communities, and particularly low- and middle-income countries (WHO, 2014, p.ix; Wang and Wang, 2020). Substandard and poverty-stricken living conditions, limited resource availability and accessibility, lost productivity, accumulating economic costs, and the increasing strain placed on healthcare systems across continents, further complicates and amplifies the reciprocative chain effects associated with NCDs. In the absence of sufficiently implemented evidence-based health promotion and NCD prevention strategies and interventions, NCDs and their related consequences will continue to grow, carving deeper into society, ultimately overwhelming the capacity of countries to address them. It is also argued that the financial benefits accruing from health promotion and NCD prevention interventions significantly outweigh the costs of developing and implementing such interventions (Nugent, 2017). Given the significant role the four key modifiable risk behavioural factors play in the permeation of the NCD pandemic, interventions aimed at informing, encouraging and supporting individuals to change their lifestyle behaviours have become instrumental in achieving the WHO's and UN's global health targets, ultimately reducing the plight of NCDs (and their associated ramifications) and NCD-attributable premature mortality rates worldwide.

## 3.3 Health Promotion: Addressing the Global Health Status on Noncommunicable Diseases and their Associated Modifiable Health Risk Behaviours

Addressing the global health status on noncommunicable diseases (NCDs) requires a thorough understanding of the concept and definition of *health*, and the *health promotion* landscape in general. According to the World Health Organisation (WHO, 2020f, p.1), health is characterised by an implied intrinsic relationship between the human body and self, and is defined as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"*. The feasibility and pragmatic realisation of this definition, however, has received a fair dose of criticism over the last several decades (Callanhan, 1973; Bice, 1976; Wood, 1986; Saracci, 1997; Larson, 1999; Jadad and O'Grady, 2008; Blaxter,

2010; Huber, et al., 2011; Huber, 2014; Huber, et al., 2016; Leonardi, 2018). Appendix A provides a detailed critical discussion and review on the debated concept of health; excluded from this main body discussion due to its extensive nature, yet is referenced and appendicised to demonstrate the researcher's understanding of the concept and definition of health. In light of the heavy criticism facing the WHO's official definition of health, and in response to the changing global health and NCD circumstances, several scholars have proposed varying alternative definitions (Saracci, 1997; Larson, 1999; Bircher, 2005; Blaxter, 2010; Huber, et al., 2011; Shilton, et al., 2011; Huber, 2014); none of which are without reasonable strengths and limitations (Amzat and Razum, 2014). A universally accepted consensus definition of health is yet to be obtained, although recent alternatives offer valuable contributions and perspectives.

A relatively recent operational definition proposed by Huber, et al. (2011, p.2) describes the concept of health *"as the ability to adapt and self-manage in the face of social, physical and emotional challenges"*. These challenges refer to NCDs and other daily-faced routine upsets (for example, missing an indoor cycling session because of traffic). Huber, et al.'s (2011) use of the term 'adapt' offers a dynamic alternate perspective to the WHO's recommended, yet impractical and unobtainable utopic, 'complete state' of health (Huber, 2014); a perpetual 'state' of being that cannot realistically be maintained (Smith, O'Grady and Jadad, 2009). Since Huber, et al.'s (2011) definition considers the diverse array of ongoing developments and contemporary shifts concerning the health and wellbeing of society and its individuals, the revised adaptive and self-management perspective is supported by other researchers, such as Shilton, et al. (2011) and Jambroes, et al. (2016). Although Huber, et al.'s (2011) definition of health is not without critiques (identified in Appendix A), the consideration for adaptation and self-management (whilst acknowledging the influences of broader social and environmental factors) hinges on the worldview orientation towards the empowerment of individuals, emphasising the ways people can learn, adapt and self-manage their own health and wellbeing in different contexts (Huber, et al., 2011; 2016).

In this thesis, the definition and perspective of health couples the WHO's and Huber, et al.'s (2011) definitions. This allows for a consideration for the adaptable and self-managerial nature of health behaviours, a proactive and preventative approach to health and NCDs (in line with the study's positioning within the field of health promotion) and the modifiability of individuals' NCD-related health risk (lifestyle) behaviours. This perspective also caters for the view that emphasises supporting, encouraging and empowering individuals to proactively

develop their own knowledge, skills and competencies as a means to adapting and self-managing their own health and wellbeing, and reducing their chances for developing NCDs or NCD comorbidities. Furthermore, an understanding of the concept of health requires its distinction from the concept of wellbeing.

While health refers to one's 'state' of being, wellbeing refers to the dynamic and life-long active 'process' of becoming aware of one's lifestyle choices, making conscious decisions and taking deliberate actions towards leading a more balanced, fulfilling and optimal existence (Seligman, 2012). Appendix A provides further detailed clarification on the distinction between health and wellbeing. Essentially, in comparison to health, the concept of wellbeing describes a broader, more holistic, multidimensional and subjective nature of people's health, and health can be thought of as a resource or stepping stone to achieving optional wellbeing. On a more granular level, health behaviours (such as physical activity and healthy eating) operate as tools for improved health, wellbeing and overall life satisfaction, and their resourceful incorporation into peoples' lifestyle patterns is integral to global NCD prevention and health promotion (Whitehead, Dahlgren and Gilson, 2001; De Chavez, et al., 2005; O'Donnell, 2009; Charlemagne-Badal, et al., 2015).

In the fight against the global NCD pandemic, the field of *health promotion* is core to the development and implementation of interventions intended to encourage, support and empower individuals to take proactive and preventative action towards modifying and changing their health and lifestyle behaviours, in order to enhance their overall health and wellbeing, and reduce their chances of developing NCDs (or a comorbid cluster of NCDs) (De Chavez, et al., 2005; WHO, 2009; Charlemagne-Badal, et al., 2015; Robinson, 2021). Health promotion is defined by the WHO (2009, p.1) as *"the process of enabling people to increase control over their health and its determinants, and thereby improve their health"*. Dr. Michael Patrick O'Donnell (2009, p.iv), the founding editor-in-chief of The American Journal of Health Promotion and CEO of the Art and Science of Health Promotion Institute, broadens this definition by describing health promotion as:

> *"The art and science of helping people discover the synergies between their core passions and optimal health, [by] enhancing their motivation to strive for optimal health, and supporting them in changing their lifestyle to move toward a state of optimal health. Optimal health is a dynamic balance of physical, emotional, social, spiritual, and intellectual health", and that individuals' "lifestyle change[s] can*

> *be facilitated through a combination of learning experiences that enhance awareness, increase motivation, and build skills".*

Health promotion strategies and policies targeting modifiable health risk behaviours and promoting positive lifestyle changes are referred to using a handful of interchangeable terms. These terms include, namely: *'lifestyle interventions'* (McLeroy, et al., 1988; O'Donnell, 2011; Seeberg and Meinert, 2015; Tabish, 2017); *'NCD prevention interventions'* (Palmer, et al., 2018); *'health promotion interventions'* (McLeroy, et al., 1988; Bartholomew, et al., 2006; O'Donnell, 2011; Bartholomew Eldredge, et al., 2016); *'health-promoting interventions'* (Uddin, et al., 2020); *'health promotion behaviour [change] interventions'* (Uddin, et al., 2020); *'health behavioural interventions'* (NICE, 2014; Conner and Norman, 2017; Stoeva, 2020); *'[health] behaviour change interventions'* (Bartholomew, et al., 2006; Webb, et al., 2010; Teixeira, 2015; Bartholomew Eldredge, et al., 2016; Michie, et al., 2018a); or simply *'health interventions'* (Conner and Norman, 2017). The interchangeable and seemingly synonymous use of these terms is even evident within the same literary articles, as illustrated, for example, in McLeroy, et al. (1988), Bartholomew, et al. (2006), O'Donnell (2011), Bartholomew Eldredge, et al. (2016), Conner and Norman (2017) and Michie, et al. (2018a). The interchangeable synonymous use of these terms demonstrates the lack of a singular universal term for labelling and describing interventions for health promotion and NCD prevention. The term *'intervention'* in particular, simply refers to any combination of strategies, mechanisms and techniques designed to stimulate and produce desirable behavioural or health outcomes (Michie, et al., 2008). For purposes of explicit clarification, the remainder of this thesis will utilise the terms *'health promotion interventions', 'health promotion behaviour change interventions'*, or *'health behaviour change interventions'*, depending on the line of argument and content being discussed within the given thesis section.

Health promotion interventions are designed using various theories, instruments, mechanisms and techniques that essentially aim to encourage and support individuals in developing and internalising knowledge, skills and abilities for modifying, improving or maintaining their own health and lifestyle behaviours (McLeroy, et al., 1988; WHO, 2009; Conner and Norman, 2017). Broader, large-scale health promotion interventions also aim to create opportunities and improve access to environments and services that affect positive health practices and make healthy lifestyle choices easier for people (Conner and Norman, 2017; De Ridder, et al., 2017). The provision of evidence-based health promotion interventions targeting modifiable health risk behaviours have become the cornerstone of global, regional and national strategies and

policies for three and a half decades (WHO, 1986; WHO, 2009; 2018a; Wingood and DiClemente, 2019; Uddin, et al., 2020). However, owing to the multifaceted societal, socioeconomic, institutional and political regulatory factors surrounding and influencing peoples' daily lifestyle behaviours, the global shifts towards the promotion of health and improved health behaviour has become a complex and challenging task (WHO, 2009; Craig, et al., 2013; Defo, 2014; Stoeva, 2020). This task is further complicated by the nuanced and not yet fully understood intricacies of human health behaviour (Defo, 2014). Given the complexity associated with health behaviour modification, a variety of multidisciplinary theoretical underpinnings and instruments are employed to inform the design of health promotion interventions that can effectively (directly and indirectly) influence positive changes in peoples' attitudes and behaviours regarding their health and wellbeing (Glanz, Rimer and Viswanath, 2015; Conner and Norman, 2017; Michie, et al., 2018a). Theoretical underpinnings generally span across fields of health psychology, cognitive psychology, behavioural psychology, sociology, sociopsychology, anthropology and the health behavioural sciences (Glanz, Rimer and Viswanath, 2015; Kelly and Barker, 2016). Furthermore, considering that humans are an inherently social species (Bandura, 1998), health promotion behavioural change interventions should be designed in ways that acknowledge and consider the socioecological and interpersonal factors that surround and influence peoples' health and lifestyle behaviours on a daily basis (McLeroy, et al., 1988; Wingood and DiClemente, 2019).

The socioecological factors, determinants and correlates of health behaviours frequently identified in literature and empirical studies as influencers for human health behaviour and behaviour modification vary considerably across the broad spectrum of global, supranational, regional, national, community, organisational and personal (that is, individual) levels (McLeroy, et al., 1988; Golden and Earp, 2012). Therefore, when developing health promotion behavioural interventions, the factors and determinants considered vary and differ in accordance with the socioecological factors and psycho-socio-behavioural determinants and correlates pertaining to a given geographic and demographic scale and a particular health context (Stokols, 1996; McLaren and Hawe, 2005; Richard, Gauvin and Raine, 2011; Punton, 2016; Brug, et al., 2017). To illustrate, take for example the different instruments and techniques used in health promotion behavioural interventions when directed at global, national, community, interpersonal and individual levels. At a global level, instruments can include guidelines and recommendations (such as the WHO guidelines for physical activity). At a national level, instruments could include taxation (such as taxes on tobacco and alcohol),

government-driven health literacy programmes (such as responsible, non-alcohol induced road driving), or legislative policies (such as no sale of tobacco or alcohol to persons under the age of 18 years). A community-level intervention could utilise mass media (such as radio stations and the internet), direct education (such as pamphlets), or organised campaigns (such as public health literacy workshops). At an interpersonal level, which are of a smaller scale than the community level, interventions can include discussion and support groups and group classes (such as group dance classes). In comparison to these levels, the individual-level health promotion behaviour interventions are more personal and particularised, and can include professional health support services (such as physician or psychiatric services) or health specialist support (such as personal trainers or nutritionists).

These examples illustrate how, when designing health promotion interventions intending to target modifiable health risk behaviours, the instruments and techniques employed will differ depending on (1) the particular health behaviour of focus, (2) the socioecological level and scale of intervention, and (3) the socioecological factors and determinants and correlates of health behaviour relevant to the geographic and demographic focus (Green, Richard and Potvin, 1996; Punton, 2016; Wingood and DiClemente, 2019). This further elucidates the complexity and intricacy involved in the design and development of health promotion interventions that target modifiable health risk behaviours. In light of the broad spectrum of socioecological factors and multifaceted complexity of health promotion behavioural change intervention design and development, this research study focuses primarily on interventions directed towards the individual and interpersonal levels.

### 3.3.1 Health Promotion at the Individual and Interpersonal Socioecological Levels

This research study focuses on health behavioural change interventions designed and delivered at the individual and interpersonal socioecological levels of health promotion. The six main justifications for this delineated focus are discussed later in this subsection. The complexities associated developing effective health promotion behaviour change interventions has given rise to decades of research and investigations into the dynamic interconnected interplay between the multidimensional arrays of varying socioecological factors and individuals' personal attributes, diverse context settings and particular modifiable health risk behaviours (McLeroy, et al., 1988; Dahlgren and Whitehead, 1991; Stokols, 1996; McLaren and Hawe, 2005; Stokols, 2018; Rubinelli and Diviani, 2020). Theoretical and empirical studies on the relations between

individual (that is, internal) and situational (that is, external) factors, and an adaptation of Bronfenbrenner's (1977; 1979) theory, gave rise to what is referred to as the *ecological* (or *socioecological*) perspective of health promotion (McLeroy, et al., 1988). This perspective remains influential two decades into the 21st century (Wingood and DiClemente, 2019; Rubinelli and Diviani, 2020).

Since the 1930s, the ecological perspective, and more specifically the socioecological approach to health promotion, has provided a consistent theoretically-grounded and evidence-based view that accounts for the complex interrelationships between individuals, health and lifestyle behaviours, epidemiology and environmental factors (Taylor, 1936; Polgar, 1962; Bandura, 1977; McLeroy, et al., 1988; Green, Richard and Potvin, 1996; Stokols, 1996; Elder, Ayala and Harris, 1999; Whitehead, Dahlgren and Gilson, 2001; Bartholomew, et al., 2006; Sallis, et al., 2006; Richard, Gauvin and Raine, 2011; Stokols, 2018; Rubinelli and Diviani, 2020). Building on the original work of Barker's (1968) ecological psychology of human behaviour, and Bronfenbrenner's (1977) ecological systems theory, McLeroy, et al. (1988) adapted and contextualised the psychological social ecological model to the field of health promotion. The socioecological systems approach is well recognised for embedding the individual within the centre of the larger social and environmental context (Bronfenbrenner, 1977; Whitehead, Dahlgren and Gilson, 2001). This central positioning of the individual describes reciprocal determinism; the notion that an individual's behaviour is mediated not only by their intrapersonal functioning, but is also mediated and determined through the complex interdependencies and mutual interactions between individuals' characteristics and the external socioecological factors that underlie peoples' health outcomes (Green, Richard and Potvin, 1996; Sallis, et al., 2006).

Figure 3.2 provides a conceptual framework of the socioecological model for health promotion. This well recognised 'onion layer' illustration is primarily based on McLeroy, et al.'s (1988) key theoretical socioecological model, and is also informed by more recent extensions and adaptions from the works of Whitehead, Dahlgren and Gilson (2001), Institute of Medicine (2002), Sallis, et al. (2006), Glanz, Rimer and Viswanath (2015) and Stokols (2018). Figure 3.2 can be conceived as a visual metaphor: a series of concentric or nested systems, each inside the other, similarly to a set of Russian dolls. In moving from the innermost system, each layer of the metaphor represents a socioecological level in which health promotion behavioural interventions can be delivered. These span across individuals (that is, intrapersonal), interpersonal (that is, social), organisational, community, societal and supranational planes,

whereby interventions can be designed to target singular, dual or multiple socioecological levels (McLeroy, et al., 1988; Whitehead, Dahlgren and Gilson, 2001; Richard, Gauvin and Raine, 2011; Stokols, 2018). Each layer contains socioecological factors as determinants and correlates that influence and are influenced by individuals' health behaviour within the larger external environment (Bronfenbrenner, 1977; McLeroy, et al., 1988; Stokols, 2018).

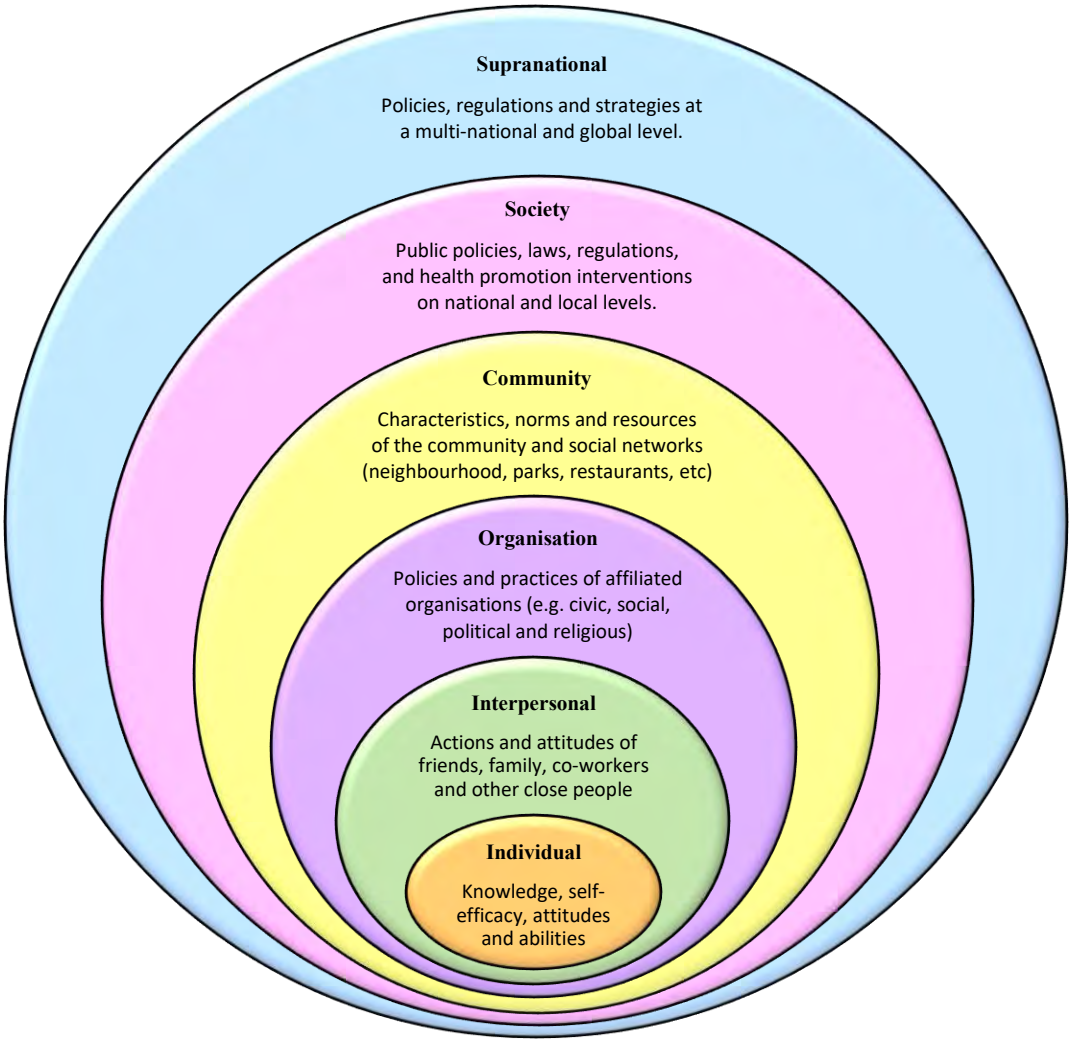



*Figure 3. 2: The Socioecological Levels of Health Promotion [Source: Researcher's own construction, adapted from Whitehead, Dahlgren and Gilson (2001), Institute of Medicine (2002), Sallis, et al. (2006), Glanz, Rimer and Viswanath (2015) and Stokols (2018)]*

McLeroy, et al.'s (1988) socioecological model of health promotion has been adapted and applied to a broad range of health contexts and modifiable health risk behaviours (Sallis, et al., 2006; Golden and Earp, 2012; Mehtälä, et al., 2014; Stokols, 2018). It has also frequently been used to provide a study theoretical foundation the design, development and evaluation of health

promotion and health behavioural change interventions worldwide (Institute of Medicine, 2002; Richard, Gauvin and Raine, 2011; Bartholomew Eldredge, et al., 2016; Stokols, 2018; Rubinelli and Diviani, 2020). The main reason for its widespread acceptance is that it provides a theoretical lens for analysing, understanding and targeting the dynamic and multifaceted interplay between individuals' intrapersonal health behavioural factors (their internal psycho-behavioural functioning) and the surrounding (external) socioecological factors that are forever influencing, shaping and reshaping individuals' health behavioural habits and lifestyle patterns (Richard, Gauvin and Raine, 2011). Examples of specific modifiable health risk behaviours and contexts in which the socioecological model of health promotion has been applied as a theoretical lens are: physical inactivity and sedentary behaviour (Sallis, et al., 2006); unhealthy eating (Townsend and Foster, 2013); smoking cessation (Kothari, et al., 2007); and harmful alcohol consumption (Gruenewald, Remer and LaScala, 2014).

Health promotion behavioural change interventions can be directed towards various layers of the socioecological model. The three main types are: (1) *multi-level* (aimed at three or more socioecological levels); (2) *dual-level* (aimed at two bordering socioecological levels); and (3) *single-level* (aimed at only one level) (Golden and Earp, 2012; Stange, et al., 2012). This research study focuses on health promotion behavioural change at the individual and interpersonal intervention levels; thereby adopting a dual-level intervention approach for promoting and addressing changes in modifiable health risk behaviour, referred to as *intra-interpersonal* health behavioural change interventions. The remainder of this section details the six justifications for this study's delineated dual-level focus – four of which relate to literature and the existing knowledge base, and two of which refer to the thesis's primary grounding discipline (the Information Systems discipline) and the empirical context (physical activity). At the end of Subsection 3.3.1, Box 3.2 provides a summary of the six justifications.

***Justification 1: Individuals as Active Agents for Modifying Their Health Behaviours***

Firstly, as depicted in Figure 3.2, people, as individuals, constitute the innermost core of society, and hence represent the active agents capable of adapting their lifestyle choices and habits through carrying out positive self-managed and self-driven changes in modifiable health risk behaviours (Teyhen, Robbins and Ryan, 2018). Sniehotta and colleagues (2017, p.e396) emphasise that "individuals are at the heart of this [socioecological] interaction", and that failing to recognise or blatantly ignoring individuals as "key elements" of the complex system of population health undermines their role as active agents of effective health promotion and

NCD prevention interventions. Individual-level health promotion interventions are generally tailored designed with the intention of targeting, supporting and effecting behavioural changes within peoples' intrapsychic workings, namely their beliefs, values, attitudes, perceptions, thoughts, knowledge, motivations, decision-making, behaviours and habits (Taylor, Lawton and Conner, 2013). Although this represents a rooted individualistic approach to intervention development, and it is necessary to acknowledge external socioecological factors of health behaviour influence, a key strength of individual (intrapersonal) level interventions is their primary aim on peoples' intrapsychic functioning. Their primary aim is usually to promote, educate, support, encourage and empower individuals to learn, develop and enhance their knowledge, skills and competencies in ways that enable them to self-adapt, cope and manage positive modifications to their health risk behaviours in the face of daily obstacles, barriers and external socioecological challenges (Golden and Earp, 2012; Punton, 2016).

Individuals' modifiable health risk behaviours can be changed over time through empowering and uplifting peoples' inner self-efficacy, self-motivation, self-reflection, self-awareness, self-confidence, self-control, self-regulation and self-competency (Bandura, 1998; Glanz, Rimer and Viswanath, 2015). Individual interventions therefore target an improvement in peoples' self-beliefs and self-perceived abilities to change, adapt and succeed in making healthier lifestyle choices and positive health behavioural adjustments (Fishbein and Yzer, 2003; Punton, 2016; Conner and Norman, 2017). Furthermore, individual-level interventions allow people to take small and incremental changes in modifying their health behaviours – a behavioural change mechanism that has demonstrated success across many studies (for example, Davis, et al. (2015) and Kwasnicka, et al. (2017)). In the context of an individual intervention intended for improving physical inactivity and sedentary health risk behaviour, a small, yet practical and achievable, incremental change would be going for a 30 minute daily walk, in line with the WHO's (2010b; 2020c) physical activity guidelines.

In terms of this research study, the focus on the individual (intrapersonal) socioecological level of health promotion allows for a perspective that simultaneously aims to promote, support and encourage people in developing skills for adapting in the face of daily challenges, whilst aiming to empower peoples' abilities to self-manage their own lifestyle choices and modifiable health risk behaviours. These two aims complement Huber, et al.'s (2011) and O'Donnell's (2009) definitions of health and health promotion, respectively, demonstrating alignment within the thesis.

***Justification 2: Individuals as Inherently Social Beings***

Secondly, human beings, by nature, are an inherently social species – an intrinsic need that governs their desire for interpersonal interactions with other individuals (Maslow, 1943). This basic interpersonal need is identifiable in individuals' efforts to connect with others as a supportive means to changing and modifying their health risk behaviours and lifestyle habits, such as joining social support networks or social groups (Donev, Pavlekovic and Kragelj, 2008). Individuals' attitudes, perceptions, thoughts and behaviours can be influenced and consequently changed through social interactions with others; involving phenomena such as social influence and social comparison (Conner and Norman, 2017). To increase their physical activity levels, for example, an individual might sign-up for a group fitness class, hire a personal trainer, join and attend gym with a friend or significant other, or engage in running, walking or cycling with friends or family members (Lachman, et al., 2018). This represents individuals' intrinsic desire and need for social support, companionship and relational encouragement (Young, et al., 2014). The lines between intrapersonal and interpersonal health behaviour change can, however, be easily blurred and crossed (Stragier, 2017; Stokols, 2018; Simeon, et al., 2020). For example, on some days, an individual might choose to go for a run alone, whereas on other days they may prefer to go for a run with friends or family members, or run with a running group, or perhaps even partake in a social event/charitable run (such as Parkrun). Therefore, it becomes apparent that although individual-level health behaviour change interventions are evidenced to be effective in isolation, the inherent human need and desire for social interaction cannot be discounted for, nor can it be disregarded (Bauman, et al., 2002; Westmaas, Gil-Rivas and Silver, 2007). This is recognisable in the rise of social media and social networking platforms within the last two to three decades (Laranjo, 2015). The blurring and crossing of boundaries between individual (intrapersonal) and social (interpersonal) factors, particularly in the digital age (Tong, Coiera and Laranjo, 2018; Petersen, Prichard and Kemps, 2019), supports the second justification for the study's delineation on the dual intra-interpersonal socioecological level – essentially an extension of the first justification.

***Justification 3: Evidence-Based Success Rates***

Thirdly, over the years, literature has frequently reported single-level individual and interpersonal, and dual intra-interpersonal level, interventions as demonstrating higher evidence-based success rates in comparison to community, public policy or societal level

interventions (Elder, Ayala and Harris, 1999; Institute of Medicine, 2002; Burke, et al., 2006; Glanz and Bishop, 2010; Richard, Gauvin and Raine, 2011; Golden and Earp, 2012; NICE, 2014; Glanz, Rimer and Viswanath, 2015; Punton, 2016; Hunter, et al., 2019). Although a larger volume of literature reports intra-interpersonal as comparably more effective, the successes achieved for a number of community, organisational, public policy and larger-scaled should not be overlooked (Punton, 2016). The evidence-based findings for these larger scale interventions are, however, often limited, inconclusive and/or inconsistent (Golden and Earp, 2012; Angus, et al., 2013; Kelly and Barker, 2016). Organisational, community and societal health promotion behavioural interventions tend to offer larger effect sizes given their broader scale of implementation (Richard, Gauvin and Raine, 2011; Punton, 2016). However, these larger scale tend to frequently (or partially) fail due to the their complexity, need for careful contextualisation, lack of appropriate underpinning theory, and limited availability of assistive and adaptable evidence-based literature; all of which are necessary for increasing the potential effectiveness of these interventions' design and delivery (Angus, et al., 2013; Schölmerich and Kawachi, 2016; Koorts and Gillison, 2018). Other issues hindering the success of multi-level interventions relates to the unpredictability of adverse and unethical consequences, considerations for individuals' possible responses, and the diverse array of demographic variables within population groups (Kelly and Barker, 2016; Conner and Norman, 2017). In short, due to the complexities and lack of evidence for multi-level interventions, and the comparable higher volume of evidence for single- and dual-level interventions, this research study focuses on the dual intra-interpersonal socioecological level of health promotion.

***Justification 4: Evidence-Based Health Behavioural Change Theory***

Fourthly, the predominant effectiveness reported on individual, interpersonal and dual intra-interpersonal level health interventions is largely attributable to their explicit, evidence-based theoretical underpinnings, which is in sharp contrast to large-scale interventions (Angus, et al., 2013; Kelly and Barker, 2016; Hagger and Weed, 2019). In other words, health promotion behaviour change interventions informed by well-documented, established, reliable, credible, evidence-based and widely accepted theoretical concepts, constructs and models are generally more effective than those lacking theoretical bases. Widely accepted reliable, credible and rigorously tested theories are frequently reported to inform the design of effective interventions, particularly because they are leveraged to identify and measure factors (determinants and correlates) that demonstrate empirical evidence for affecting health behavioural change (Michie, 2008; Michie, et al., 2008; Glanz, Rimer and Viswanath, 2015;

Bohlen, et al., 2019). These reliable and evidence-based individual and social theories have been developed, reviewed and extended over decades of progressive research, giving rise to what is commonly referred to as *behavioural science (or behavioural change) theory* (Kerlinger, 1979; Michie, et al., 2008; Kwasnicka, et al., 2016). These theories share roots in several fields of study, ranging psychology, sociology, socio-psychology, behavioural sciences, and health sciences (Glanz and Bishop, 2010).

The utilisation and application of behavioural change theory has demonstrated noteworthy evidence in promoting healthier lifestyle habits and in influencing positive changes in modifiable health risk behaviours on the intrapersonal, interpersonal and dual intra-interpersonal socioecological levels (Kohl, et al., 2012; Prestwich, Webb and Conner, 2015; Kwasnicka, et al., 2016; Hagger and Weed, 2019). Behavioural change theories generally employ theories, frameworks/models, concepts and constructs that target people's beliefs, values, perceptions, attitudes, knowledge, skills, abilities, intentions, motivations and other self and social related behaviour (such as self-awareness, self-efficacy, self-management, social cognitive theory and social practice theory) to guide people towards their desired health behavioural outcomes (Bandura, 1977; Prestwich, et al., 2014; Glanz, Rimer and Viswanath, 2015).

The pool of theories suitable for underpinning and informing the design of single- and dual-level interventions outweigh theories available for multi-level levels (Glanz and Bishop, 2010; Schölmerich and Kawachi, 2016). This is because multi-level theories need to account for a multitude of interrelated and complex socioecological factors that influence and are influenced by individuals' daily lifestyle and health behaviours within largely diverse environmental, political, socioeconomic, cultural and social demographic contexts (Schölmerich and Kawachi, 2016). The lack of evidence-based theories for multi-level interventions relates to their frequently reported failures (or partial failures) (Prestwich, Webb and Conner, 2015). Moreover, the "limited" (Schölmerich and Kawachi, 2016, p.18) and "essentially absent" (Golden and Earp, 2012, p.368) availability of multi-level theories hinders the progress made in "bridging the gap" between theory, empirical findings and real-world practice (Steinmo, et al., 2016). This is an important issue consider that the documenting, reporting and disseminating of what works and what fails is necessary for improving the design and effectiveness of health behaviour interventions (Hoffmann, et al., 2014). In contrast, the long documented reporting of evidence-based individual and social behavioural change theories,

and their empirical backing, supports the fourth justification for a focus on the design of interventions at the dual intra-interpersonal socioecological level of health promotion.

***Justification 5: Research Study Resource and Time Limitations***

The fifth reason relates to the empirical study, and concerns the infeasibility and impracticality foreseen if this research project were to be carried out in the context of evidently complex, multi-factorial multi-level interventions. Several studies have highlighted and argued the "unrealistic" (Golden and Earp, 2012, p.368) expectations associated with multi-level interventions, emphasising their need for a "multi-pronged approach" (Golden and Earp, 2012, p.370), which requires multi- and interdisciplinary stakeholder involvement and a substantial volume of resources, capital and time, along with considerable economic, political and public policy influence (Stokols, 1996; Institute of Medicine, 2002; Kelly and Barker, 2016; Schölmerich and Kawachi, 2016). Therefore, in considering the broad spectrum and multitude of varying reciprocative interrelationships between external socioecological factors and individuals kernelled therein, along with the lack of documented evidence-based success and limited availability of health behavioural science theory (discussed above), this research study does not focus on multi-level health promotion behavioural change interventions. Although a multi-level approach can be beneficial reaching large-scale population groups (Conner and Norman, 2017), it is infeasible and unrealistic in terms of the resources, capital and time available for this particular research project. Moreover, the current "lack" (Schölmerich and Kawachi, 2016, p18) of multi-level applicable theories is further complicated when designing health behavioural change interventions intended for delivery via digital technology platforms – as is the case in this thesis (discussed in Chapter 1; further detailed in Chapter 4).

***Justification 6: The Blurred Lines Between Individuals and Digital Social Connectivity***

The sixth and final justification for the research study's focus on the dual intra-interpersonal socioecological level of health promotion relates to the last point made (in justification 5) on the use of digital technology as an increasingly powerful mode for delivering health promotion behaviour change interventions. In light of the modern socially-interconnected digital age, the boundaries between the individual (intrapersonal) and social (interpersonal) socioecological levels of intervention have become increasingly blurred and integrated (Stragier, 2017; Stokols, 2018; Tong, Coiera and Laranjo, 2018; Petersen, Prichard and Kemps, 2019; Simeon, et al., 2020). Key to note is that the individually-focused behavioural change techniques and mechanisms are primary, and the socially-orientated behavioural change techniques and

mechanisms are supplementary, thereby providing secondary and contributory support for health behaviour modification. This can be demonstrated in the use of digital mobile platforms to deliver physical activity behaviour change interventions. Mobile applications (apps) for running, for example, are primarily designed to provide individuals (as device users) with running-related information, support and encouragement, although most running apps contain a secondary feature that offers users opportunities to connect with or share performance running data with other runners. This is an example of how, in the context of mobile app technology, the increasingly globalised, digitised and socially-connected era has blurred the lines between the design and delivery of individual-level and interpersonal-level health promotion behaviour change interventions, thus suggesting a dual intra-interpersonal approach to modifying peoples' health risk behaviours.

**Justifications for Research Study Delineation to the Dual Intra-Interpersonal Socioecological Level of Health Promotion**

1. As the core active agents nested within the larger socioecological context, individuals play a central role in self-managing and adapting their modifiable health behaviour. Interventions that target intrapsychic functioning and that aim to educate, support and encourage people to positively modify their health risk behaviour are key to empowering individuals towards leading healthier lifestyles.
2. Individuals' inherent need and desire for social interaction, and the influence of social engagement on their daily health and lifestyle behaviours cannot be disregarded, particularly in the context of physical activity participation (such as running, sport and exercise behaviours).
3. The evidence-based success rates for individual, interpersonal and dual intra-interpersonal level interventions are significantly more substantial and well documented than the evidence available on complex multi-level interventions, which often report fewer, inconsistent and inconclusive success rates.
4. The existing pool of evidence-based and credible behavioural science (or behavioural change) theory outweighs theory available on complex multi-level interventions. Theory is necessary for documenting and reporting effective determinants and correlates of health behaviour, and for grounding and informing the behavioural change techniques and mechanisms that constitute the design of health behaviour change interventions.
5. A consideration for the limited resources available for the research study, and with the need for interdisciplinary stakeholder involvement and sizeable economic and political influence for multi-level interventions, the intra-interpersonal scope is comparably more suitable, yet sufficient, for making a valuable knowledge contribution.
6. In the digital age, and particularly in the context of technology-based health interventions, the lines between intrapersonal and interpersonal mechanisms have become increasingly blurred, with social networking and social media platforms becoming increasingly embedded into individuals' daily lifestyle patterns and behaviours.

*Box 3. 2: Justifications for Research Study Delineation to the Dual Intra-Interpersonal Socioecological Level of Health Promotion [Source: Researcher's own construction]*

The socioecological perspective and the above six justifications (summarised in Box 3.2) provide insight into the complexity and intricacies associated with the design, development, evaluation and delivery of successful health promotion behaviour change interventions;

particularly those orientated towards modifiable health risk behaviours (such as insufficient physical activity, poor dietary intake, excessive alcohol consumption, and tobacco smoking). The points highlighted and discussed throughout Subsection 3.3.1 hint towards the necessary and imperative need for understanding that in order to design effective health promotion behaviour change interventions, careful consideration should be given to the theoretical- and evidence-based links between: (1) the socioecological intervention level(s) (that is, the intended audience or target group); (2) the specific target behaviour (that is, the identified modifiable health behaviour); (3) the underpinning behavioural change theories related to the target behaviour; (4) the behavioural changes required in working towards and achieving the target behaviour outcomes; and (5) the mode of intervention delivery (that is, the means or platform through which the intervention is delivered to the intended audience) (Wright, et al., 2015; Michie, et al., 2018a; Biddle, et al., 2021).

In terms of this research study, there is a scoped contextual delineation to physical activity domain, in other words, a focus on physical activity as a modifiable health risk behaviour. Considering the broad range of health behavioural change theories, theoretical concepts and constructs, determinants and correlates of health behaviour, and behavioural change techniques and mechanisms, and their varying relevance and applicability to different modifiable health behaviours, a particularised focus on one health behaviour domain allows for a scoped thesis and primary empirical study focus.

## 3.4 Health Promotion and Behaviour Change in the Context of Physical Activity

*Those who think they have not time for bodily exercise will*
*sooner or later have to find time for illness.*
*– Edward H. Stanley (1873) –*

### 3.4.1 The Role of Physical Activity in Fighting Noncommunicable Diseases: The Global Physical Inactivity Pandemic

Insufficient physical activity is a leading risk factor for noncommunicable diseases worldwide (Lee, et al., 2012; Guthold, et al., 2018; WHO, 2018a; 2021). Physical inactivity increases the risk of heart disease, stroke, diabetes and several cancers by 20 to 30 percent (WHO, 2020e). Every year, between four and five million deaths could be averted if the global population were more physically active (Strain, et al, 2020; WHO, 2020c; 2020e). Globally, one in four adults and 81% of adolescents do not meet the WHO's recommended levels of physical activity

(Uddin, et al., 2020; WHO, 2020c; 2020e). Within recent years, the prevalence of physical inactivity has repeatedly been described as a global "pandemic" (Kohl, 2012, p.294; Ding, et al., 2016, p.1311; Ding, 2018, p.e1046; Hall, et al., 2021, p.108). At the current rate of physical inactivity trends worldwide, the WHO's (2013) global action plan to achieve at least a 10% relative reduction in the global prevalence of insufficient physical activity, will not be met (Guthold, et al., 2018; Hall, et al, 2021). The anticipated failure to meet this goal has been made worse by the global COVID-19 pandemic, which has had a discernable impact on peoples' levels of physical activity (McLaughlin, Takami and Lin, 2020; WHO, 2020d; Hall, et al., 2021). It is predicted that "all data convincingly indicates the physical inactivity pandemic will persist long after we recover from the COVID-19 pandemic", and that the associated health and economic impacts of physical inactivity "will continue to be severe" (Hall, et al., 2021, p.108).

The associations drawn between physical activity and sedentary behaviour, and their long term negative impact on the health and wellbeing of individuals, dates back to the fifteenth century BCE (McKenzie, 1909; Hippocrates, 1923; Tipton, 2014). Two centuries ago (460 BCE to 370 BCE), Hippocrates – referred to as the Father of Western Medicine – explained that *"exercise should be many and of all kinds"* and that *"eating alone will not keep a man well; he must also exercise ... for food and exercise together produce health"* (Plasker, 2010, p.190). Hippocrates further emphasised that if the human body is *"unused"* and *"left idle"* (that is, not sufficiently exercised), people will *"become liable to disease"* (Ruegsegger and Booth, 2018, p.1). While ancestral mankind daily living involved behaviours that demanded ample energy expenditure and general cardiovascular health and physical strength and stamina (such as foraging for food and resources), the industrial movements and modern-day advances in technology have had significant negative effects on the general extent of peoples' daily physical activity engagements, and consequentially, their overall physical health and wellbeing (Rhodes, et al., 2017).

The strong, inverse correlation between physical activity, health, disease and overall mortality in individuals is evidenced by decades of research and large, long-term epidemiological studies (Morris, et al., 1953; Leon, 1985; Paffenbarger, et al., 1993; Fletcher, et al., 1996; WHO, 2010a; Kohl, et al., 2012; Lee, et al., 2012; Rhodes, et al., 2017; Guthold, et al., 2018; WHO, 2018a; 2020c; 2021). A pooled analysis of 358 population-based surveys across 168 countries (including nearly 2 million participants) found that, from 2001 to 2016, the highest levels of insufficient physical activity were identified in Latin America, the Caribbean, high-income

Western countries and high-income Asia Pacific (Guthold, et al., 2018). Although physical inactivity trends widely vary across countries, regions and income groups, the largest increases in physical inactivity and sedentary behaviour have occurred in high-income countries (more than double the prevalence of low-income countries), whereas the largest decreases have occurred in east and southeast Asia (Guthold, et al., 2018). As countries develop economically, physical inactivity levels can reach as high as 70%, due to cultural values, changing transport patterns, urbanisation, the increased integration and use of digital technology into daily work and recreational living, and increased sedentary behaviours (WHO, 2018a). Paradoxically, as economies develop and levels of insufficient physical activity rise, the associated economic burden on society and healthcare systems continues to grow (Nugent, 2017; Ding, 2018).

The global cost of physical inactivity is estimated to be INT$ 53.8 billion per year in direct healthcare, with an additional INT$ 14 billion attributable to lost productivity (INT$ represents the Geary-Khamis international dollar; Khamis (1984)) (Ding, et al., 2016; WHO, 2018a). The public, private and household sectors proportionately pay 58%, 24% and 18%, respectively, of the total INT$ 53.8 billion, annually (Ding, et al., 2016). North America and the Western Pacific, which comprise many high-income countries, contribute INT$ 25.7 billion and INT$ 9.2 billion, respectively, to the global INT$ 53.8 billion every year (Ding, et al., 2016). Several other studies reveal the direct and indirect healthcare costs of physical inactivity as substantial proportions of countries' annual economic expenditures (Bloom, et al., 2011; Janssen, 2012; Bloom, et al., 2013; Acs, et al., 2020), corresponding to the global estimates. In short, the physical inactivity pandemic is not only associated with significantly contributing to the development of NCDs and premature mortalities, but also places a considerable direct and indirect cost burden on the global healthcare system and countries across the world.

## 3.4.2 Addressing the Global Physical Inactivity Pandemic

### 3.4.2.1 Understanding Physical Activity and its Global Guidelines

Addressing the global physical inactivity pandemic and designing health promotion interventions intended to target physical activity behaviour change requires a thorough understanding of the concept and construct of physical activity (and its relation to the concept of sedentary behaviour) as well as an understanding of what constitutes 'sufficient' versus 'insufficient' levels of physical activity worldwide. These insights inform the design, development, implementation and evaluation of health promotion physical activity behaviour change interventions.

The term *physical activity*, to the lay public, is an easily digestible word; however, its concept is often used colloquially without a clear picture of its constituents. *Physical activity* is an umbrella term defined as *"any bodily movement produced by skeletal muscles that results in energy expenditure"* (Caspersen, Powell and Christenson, 1985, p.126) that can be categorised into two main types, namely: leisure-time physical activity and occupational physical activity (Howley, 2001). Leisure-time physical activity, on the one hand, broadly describes a number of activities in which an individual participates in their free time, such as: exercise programs, walking, gardening, dancing, sporting games, swimming and cycling. Occupational physical activity, on the other hand, relates to any activity associated with the performance of an individual's job, for example: pushing, hauling, walking, lifting, shovelling, packing boxes and carpentry (Howley, 2001). In colloquial speak, the concept of *physical activity* is also frequently misused interchangeably with the terms *physical fitness* and *exercise*. In comparison to physical activity, *physical fitness* describes a set of attributes that are either health-related (such as muscular strength, muscular endurance and cardiorespiratory endurance) or skill-related (such as balance, speed, coordination and agility) (Caspersen, Powell and Christenson, 1985; Howley, 2001). Whereas *exercise* (or exercise training) is a subcategory of leisure-time physical activity that is "planned" and "structured" (Caspersen, Powell and Christenson, 1985, p.126) in which "repetitive bodily movements are performed to improve or maintain one or more components of physical fitness" (Howley, 2001, p.s364). Table 3.1 provides a summary of some basic and familiar terminology that is accepted and used universally by researchers and practitioners within the physical activity field of study.

*Table 3. 1: Definitions of Terminology used within the Physical Activity Domain [Source: Adapted from Caspersen, Powell and Christenson (1985), Howley (2001), WHO (2010b; 2018a; 2020c)]*

| **Definitions of Terminology used within the Physical Activity Domain** |
|---|
| **Physical activity** |
| **Physical activity:** Any bodily movement produced by skeletal muscles that requires energy expenditure. |
| **Physical inactivity:** An insufficient physical activity level to meet current minimum physical activity recommendations. |
| **Physical fitness:** A set of attributes that are either health-related (e.g. muscular strength, muscular endurance and cardiorespiratory endurance) or skill-related (e.g. balance, speed, coordination and agility). |
| **Exercise (exercise training):** A subset of physical activity that is planned, structured, repetitive and purposeful, with the objective to improve or maintain physical fitness. |

| Three Types of Exercise Training and Components of Physical Fitness |
|---|
| **Aerobic exercise (endurance activity or cardiorespiratory endurance):** Activity in which the body's large muscle groups move in a dynamic and rhythmic manner for a sustained period of time, leading to an increase in heart rate and energy expenditure, which enhances circulatory and respiratory system functioning. Examples include brisk walking, running, cycling, swimming and jumping rope. |
| **Anaerobic exercise:** Short-duration exercise training performed at very high intensities, with the aim to improve musculoskeletal strength – where oxygen demand exceeds oxygen supply, and where a large portion of the energy expenditure is provided by glycolysis and stored phosphocreatine. Examples include sprinting, powerlifting, high intensity interval training and weight training. |
| **Resistance exercise:** Training (related to anaerobic exercise) that is designed to increase muscular strength, power and endurance by varying the weighted resistance, the number of repetitions a single group (set) of resistance is performed (i.e. reps), the number of sets performed, and the rest interval duration between reps and sets. Examples include weight training, machine weights, free weights, resistance bands, body weight training. |
| **Skill-Related Components of Physical Fitness** |
| **Agility:** The ability to rapidly change the position of the entire body in space with speed and accuracy. |
| **Balance:** The ability to withstand challenges from postural sway or destabilising stimuli caused by self-motion, the environment or other objects; the maintenance of equilibrium while stationary or moving. |
| **Coorindation:** The ability to use the senses (such as sight and hearing) together with body parts in performing motor tasks smoothly and accurately. |
| **Flexibility:** The range of motion available at a joint, and can relate to ligament and tendon tightness. |
| **Muscular endurance:** The ability of muscle groups to exert external force for many repetitions or successive exertions. |
| **Muscular strength:** Skeletal muscular strength, power, endurance and mass; the amount of external force that a muscle can exert. |
| **Power:** The rate at which an activity can be performed. |
| **Reaction time:** The time elapsed between stimulation and the beginning of the reaction to it. |
| **Speed:** The ability to perform a movement within a short period of time. |

The concept of *physical activity* is also distinguishable from *sedentary behaviour* (González, Fuentes and Márquez, 2017; Van der Ploeg and Hillsdon, 2017; Tremblay, et al., 2017). *Sedentary behaviour* can be described as any waking behaviour in which an individual's energy expenditure is equal to, or less than, 1.5 of their own METs (metabolic equivalent of tasks) (Tremblay, et al., 2017; WHO, 2020c). Sedentary behaviour can be performed while in a sitting or reclining posture (WHO, 2020c) and involves activities such as lying down, watching television, sitting at a desk or computer, reading, driving a vehicle and screen-based entertainment (Tremblay, et al., 2017). Although sedentary behaviour in itself is not hazardous to health, it is evidenced as detrimental in higher volumes (which are unbalanced with sufficient physical activity) (González, Fuentes and Márquez, 2017; WHO, 2020c). Sedentary behaviour also carries its own independent health risks (separate to that of physical inactivity) and is therefore recognised as a modifiable health risk behaviour independent of, yet related to,

physical inactivity (that is, insufficient levels of physical activity; WHO, 2010a; 2020c) (Dogra and Stathokostas, 2012; González, Fuentes and Márquez, 2017; Van der Ploeg and Hillsdon, 2017). Box 3.3 provides two short examples to further clarify the distinction between physical activity/physical inactivity and sedentary behaviour.

**Distinguishing Between Physical Activity/Physical Inactivity and Sedentary Behaviour: Examples**

Ashley drives to work in the morning and for the most part of the day, sits behind her desktop computer and in meetings. After work, Ashley drives back home and spends most of her evening sitting watching television. This indicates that Ashley is someone who participates in high levels of sedentary behaviour (classified by ≥4 waking hours/day). However, for five days a week, before going to work, Ashley goes to gym in the early morning, where she engages in moderate-intensity 30 minute runs on the treadmill (aerobic exercise) and does 30-45 minutes of weight training (resistance exercise), which puts her on target for meeting the WHO's sufficient levels of daily physical activity (guidelines outlined below). Ashley's example of daily physical energy expenditure is highly sedentary, but also sufficiently physically active.

In comparison to Ashley, Déon is a full-time hairdresser whose job requires a substantial amount of walking and light-intensity physical activity daily, classifying him as an individual with low levels of sedentary behaviour (classified by ≤2 waking hours/day). Déon is also a single father, which means that before going to work in the mornings and when returning from work in the late afternoon, he spends most of his time engaging in light-intensity physical activity when tending to his two children. Déon, however, does not engage in moderate- or vigorous-intensity physical activity, deeming him insufficiently physically active (in terms of the WHO's guidelines outlined below). Déon's example of daily physical energy expenditure is low in sedentary behaviour, but also high in physical inactivity.

*Box 3. 3: Distinguishing Between Physical Activity/Physical Inactivity and Sedentary Behaviour: Examples [Source: Researcher's own construction]*

In light of the distinctions between physical activity and sedentary behaviour, and their independent, albeit related, influence as modifiable health risk behaviours for NCDs and premature mortality (WHO, 2020c), the recommended guidelines (WHO, 2010b; 2020e) and behavioural change intervention techniques and mechanisms used in interventions (Rhodes, et al., 2017; Wang, 2019) differ. Moreover, while the classifying and measuring of physical activity as a construct holds universal validity and reliability (WHO, 2010b, 2020c), controversial debates continue regarding the classifying and measuring of sedentary behaviour as a construct, the relative recency of its associated official guidelines (published in 2020, 10 years after the official physical activity guidelines), and the comparatively lesser availability of evidence and literature (Van der Ploeg and Hillsdon, 2017; Bull, et al., 2020; Dempsey, et al., 2020). For these reasons, and to maintain a specific contextual focus, this research study is

delineated to the physical activity domain, and although the importance and role of sedentary behaviour in NCD prevention is acknowledged, no further discussions will be provided on the sedentary behaviour context or the recently published sedentary behaviour guidelines (WHO, 2020c).

The WHO's recommended guidelines for sufficient levels of physical activity were initially published in 2010, and officially updated a decade later in 2020 (WHO, 2010b; 2020c). Based on existing guidelines across the world, the WHO's recommendations offer universal, scientifically-informed and evidence-based guidance on the dose-response relationship between physical activity, its associated health benefits, and the minimum levels of physical activity engagement necessary for health maintenance and reduced risk for NCD (or NCD comorbid cluster) development (WHO, 2010b; 2020c). The guidelines essentially convert the concept of physical activity into a construct that can be broken down and universally measured, documented, reported, compared and disseminated, feeding the knowledge base of physical activity and the global physical inactivity pandemic.

As a function of physical activity, the guidelines take into account the type, duration, intensity, frequency and volume of bodily movement and performance, as a reliable measure for physical activity participation (WHO, 2010b; 2020c). Table 3.2 provides a summary of the key terms used to describe and outline the WHO's physical activity guideline recommendations. While these terms (Table 3.2) are relatively colloquial, there are many other specialised, scientific terms (domain jargon) relating to physical activity, physical fitness and exercise training performance that are used meticulously in referring to, measuring and calculating physiological responses, anthropometric changes and energy expenditure associated with physical activity. Some of these constructs include: heart rate (minimum and maximum); metabolic rate (resting and exercise); rate of perceived exertion; oxygen uptake ($VO_2$ max); acute health effects; chronic training effects; reaction time; body composition; body mass index (BMI); caloric burn; and many hormone responses (Howley, 2001). These scientific terms for physiological measurement will not be reviewed in this thesis given this section's aim is to provide a high-level introductory overview of the physical activity context, rather than conduct physical activity empirical data studies. Table 3.2 also provides specifies three key terms used frequently in the WHO's physical activity guidelines, namely light-intensity, moderate-intensity and vigorous-intensity (WHO, 2020c).

*Table 3. 2: Definitions of Terminology for Describing the Variables Used in the WHO's Global Physical Activity Guidelines [Source: Adapted from WHO (2010b; 2020c)]*

| **Definitions of Terminology for Describing the Variables Used in the WHO's Global Physical Activity Guidelines** |
|---|
| **Variables used in describing physical activity dosage** |
| **Type of physical activity (what type):** The mode, form or type of physical activity. Such as aerobic, anaerobic, resistance, agility, flexibility and strength training. |
| **Duration (how long):** The length of time in which the activity is performed; generally expressed in minutes or seconds. |
| **Intensity (how hard a person works to do an activity):** The magnitude of effort required or rate at which an activity is performed. |
| **Frequency (how often):** The number of times an activity is performed; generally expressed in episodes or sessions per week. Frequency can also refer to the number of times an activity is performed within one workout; generally expressed in repetitions (i.e. reps), sets or circuits. |
| **Volume (total amount):** The total amount of exercise training, calculated by the function of frequency, duration and intensity an activity. |
| **Levels of Intensity*** |
| **Light-intensity:** On an absolute scale, light intensity is between 1.5 and 3 METs (i.e. activities with energy cost less than three times the energy expenditure at rest for any given person). On a scale relative to an individual's personal capacity, light intensity varies between 2 and 4 on a scale of 0-10. Examples include slow walking, bathing or other incidental activities that do not result in a substantial increase in heart rate or breathing rate. |
| **Moderate-intensity:** On an absolute scale, moderate intensity is performed at 3.0-5.9 METs (i.e. activities with energy cost more than three, but less than 6, times the intensity at rest for any given person). On a scale relative to an individual's personal capacity, moderate intensity varies between 5 and 6 on a scale of 0-10. |
| **Vigorous-intensity:** On an absolute scale, vigorous intensity is performed at 6.0 or more METs (i.e. activities with energy cost more than 6 times the energy expenditure at rest for any given person), and 7.0 or more METs for children and adolescents. On a scale relative to an individual's personal capacity, vigorous intensity varies between 7 and 8 on a scale of 0-10. |
| **Intensity varies between people, depending on previous activity or exercise experience and their relative level of fitness and strength.*<br>*†MET (metabolic equivalent of task) is a physiological measure expressing the intensity of physical activities. 1 MET is the energy equivalent expended by an individual while seated at rest.* |

These basic terms and particularly the three levels of intensity (outlined in Table 3.2) are central to interpreting the WHO's (2010b; 2020c) global physical activity guideline recommendations, which hence informs what constitutes sufficient and insufficient levels of physical activity. An illustrative summary of the WHO's (2010b; 2020c, p.viii) main physical activity guideline recommendations for persons with "all abilities" is provided in Figure 3.3. These recommendations are relevant for all populations and age groups, irrespective of gender, cultural background or socioeconomic status, and are relevant for people of all abilities (WHO,

2020c). For persons living with chronic medical conditions (such as hypertension and type II diabetes) and/or disability, and for pregnant and postpartum women, physical activity guideline recommendations and good practice guidelines somewhat differ (WHO, 2020c). For guidelines applicable to these groups of persons, please refer to the WHO's recently published updated guidelines (WHO, 2020c). Considering that this research study does not focus on physical activity engagement within any particular group(s) of persons, these group-specific guidelines are not included in Figure 3.3. As depicted in Figure 3.3, the WHO's (2010b; 2020c, p.viii) guidelines for persons with "all abilities" is categorised into three distinct age groups, namely (1) *children and adolescents* (5 to 7 years of age), (2) *adults* (18 to 65 years of age), and (3) *older adults* (65 years of age and older).

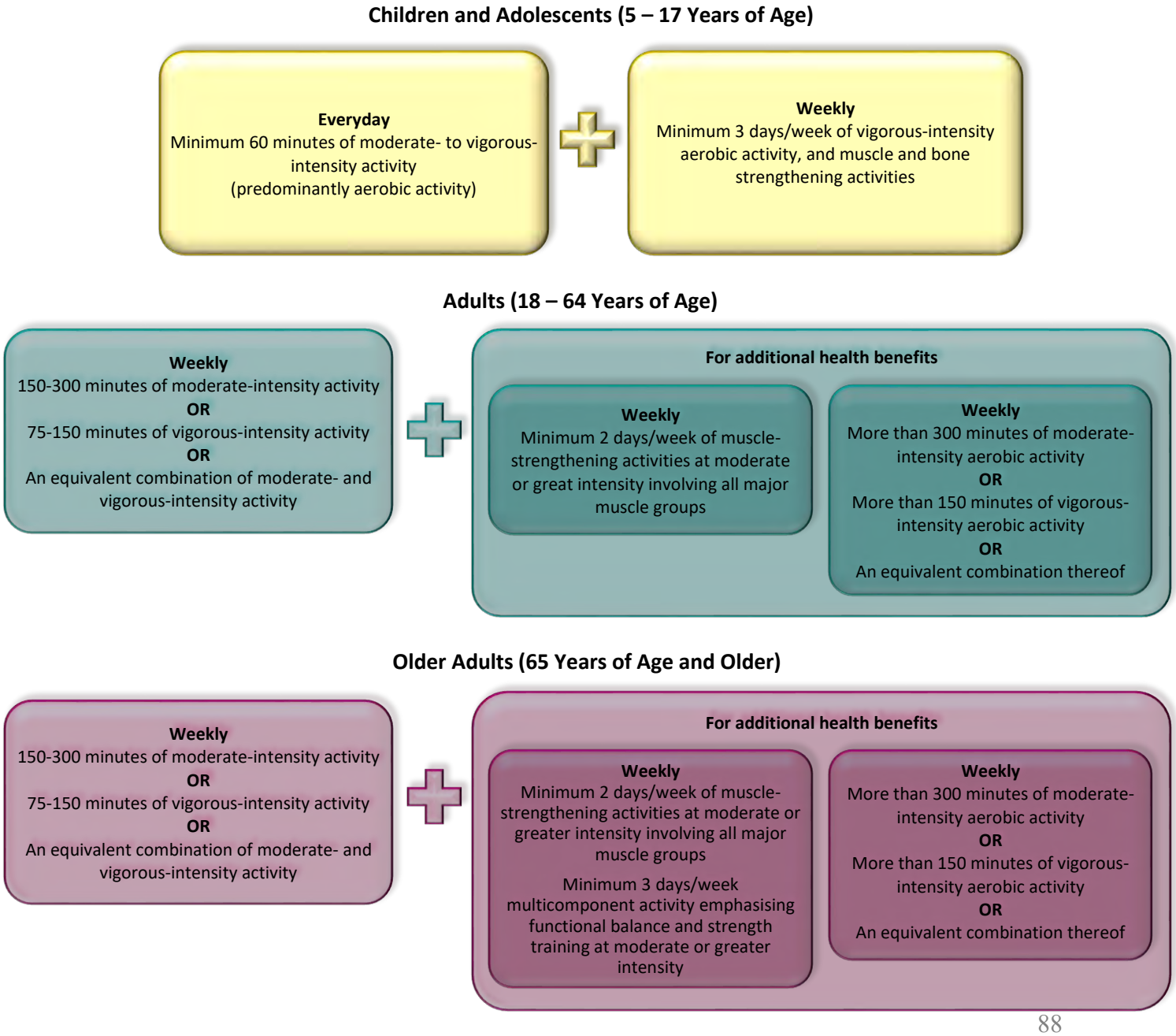





*Figure 3. 3: WHO Global Physical Activity Guideline Recommendations (for Persons with all abilities) [Source: Researcher's own construction, adapted from WHO (2010b; 2020c)]*

The WHO's physical activity guideline recommendations have two primary purposes, namely (1) to educate and raise awareness of the importance of physical activity in the global public, and (2) to be used by policy-makers, government officials and non-government organisations in low-, middle- and high-income countries to inform strategy/plan development, education, healthcare provision and research (WHO, 2020c). The recently updated guidelines also coincide with the WHO's *Global Action Plan on Physical Activity 2018-2030* (WHO, 2018a; Bull, et al., 2020).

#### 3.4.2.2 Addressing the Global Physical Inactivity Pandemic with Health Promotion Interventions for Physical Activity Behaviour Change

The WHO's most recently updated and published *Global Action Plan on Physical Activity 2018-2030* (WHO, 2018a; Bull, et al., 2020) outlines a target for a 15% relative reduction in the global prevalence of physical inactivity in adults and adolescents by 2030. The plan adopts a socioecological systems approach (presented in Subsection 3.3.1) that considers all levels of intervention for physical activity promotion to lay out four strategic objectives and a universally applicable framework for twenty multidimensional evidence-based policy actions that countries across the world can adapt and implement within their given contexts (WHO, 2018a). Countries' investments in carrying out the global action plan and implementing physical activity interventions have multiplicative health, social and economic benefits, and contributes directly and indirectly to achieving thirteen of the United Nation's (UN) sustainable development goals (SDGs 2-13, 15-17) (UN, 2015; Guthold, et al., 2020; WHO, 2020c).

In addition to the recently updated 2018-2030 global action plan, the WHO has also published other global physical activity related strategies and plans. These include the prior *Global Strategy on Diet, Physical Activity and Health* (WHO, 2004) and the *Global Action Plan for the Prevention and Control of NCDs 2013-2020* (WHO, 2013). The latter of which outlines one of its primary key targets as reducing global physical inactivity levels by a relative 10% by 2025; a goal that is foreseen to be unobtainable within the remaining four-year timeframe (as discussed before in Subsection 3.4.1) (Guthold, et al., 2018; Hall, et al, 2021). Many strategies, policies and other forms of interventions for promoting physical activity behaviour change are also carried out on national, regional and local levels (for example, VicHealth, 2019; African Physical Activity Network, 2020); many of which advocate for and align with the socioecological approach to health promotion (Mehtälä, et al., 2014; WHO, 2018a).

The WHO's global physical activity guideline recommendations provide an additional form of intervention carried out to address the physical inactivity pandemic, promote general physical activity behaviour change in countries across the world, and to inform countries' development and implementation of physical activity related policies, strategies and action plans (WHO, 2010b; 2020c). However, despite these efforts to improve peoples' physical activity levels, many studies reveal children, adolescents and adults as largely not meeting the guidelines for sufficient physical activity engagement (Hallal, et al., 2012; Kohl, et al., 2012; Das and Horton, 2016; Rhodes, et al, 2017; Blackwell and Clarke, 2018; Ding, 2018; WHO, 2018a; Guthold, et al., 2020; WHO, 2020e). Findings also reveal a general lack of awareness of and knowledge about the WHO's physical activity guidelines and the associated benefits of sufficient physical activity (for example, shown to reduce the risk of at least 25 NCDs) (Rhodes, et al., 2017; Abula, et al., 2018; Hallal, et al., 2021). Furthermore, despite the WHO's and countries' efforts to promote physical activity behaviour change in their citizens and increase their awareness of recommended physical activity levels, evidence supports the observation that "physical activity is not improving worldwide", and that "the world needs to get serious about physical activity" as a matter of global "urgency" (Das and Horton, 2016, p.1254). These findings suggest that despite global efforts to educate people on what constitutes sufficient physical activity, and efforts to promote increased activity participation, public education and awareness campaigns are not adequate enough for motivating realised changes in peoples' daily physical activity behaviours. As a result, research into the design, development and delivery of physical activity behavioural change interventions at single, dual and multiple socioecological levels of health promotion remains relevant, paramount and ongoing (Yen and Li, 2019; Rhodes, et al., 2020; Rubinelli and Diviani, 2020).

While external socioecological (organisational, community, societal and supranational) factors are recognised as playing an important and influential role in addressing physical activity at the population level, it is crucial to keep in mind that in order to improve population-level physical activity behaviour, individuals should be recognised as "key elements" of the system – "active agents" lying at the "heart" of the socioecological model (Sniehotta, et al., 2017, p.e396). Furthermore, interventions delivered at the individual level have shown to "reach millions of individuals and have an indisputable effect on population health"; their power to affect large-scale change should not be discounted (Sneihotta, et al., 2017, p.e396). Research into the design and delivery of individual and interpersonal level physical activity interventions therefore remains a current and relevant area of study, even more so as the power of digital

technology is increasingly leveraged to deliver tailored physical activity behaviour change interventions to millions of individuals worldwide (Stokols, 2018; Kickbusch, 2019; Kwan, et al., 2020; NICE, 2020). At the individual and interpersonal levels of intervention, research remains ongoing into investigating and understanding the determinants and correlates of physical activity, as well as which factors, behavioural change techniques and mechanisms are evidenced to show positive, empowering and self-adaptable changes in peoples' daily physical activity behaviours (Aleksovska, et al., 2019; Rhodes, et al., 2020; Schroé, et al., 2020; Simeon, et al., 2020; Zeiher, et al., 2020).

## 3.5 Designing Health Promotion Behaviour Change Interventions for Physical Activity at the Dual Intra-Interpersonal Socioecological Levels

"Understanding behaviour is key to changing it" (Michie, 2013, p.4). Designing and developing health promotion interventions for physical behaviour change at the dual intra-interpersonal socioecological levels requires an understanding of which factors and mechanisms are evidenced to be effective at motivating and affecting realised change (Gourlan, et al., 2016; Rhodes, McEwan and Rebar, 2019; Taj, Klein and van Halteren, 2019). Intervention designers therefore need to carefully consider which (1) *theories*, (2) *determinants and correlates*, and (3) *techniques*, or combinations thereof, will be used to inform the design and component structure of physical activity behaviour change interventions (Michie, et al., 2008; Rhodes, et al., 2017; Steinmo, et al., 2018; Rhodes, McEwan and Rebar, 2019; Schroé, et al., 2020). The selection of these ingredients is informed by the intervention's intended objectives – including the target behaviour, target behavioural outcomes, target audience, target socioecological level, behavioural change mechanisms, and mode of intervention delivery (Bartholomew Eldredge, et al., 2016). Theories, theoretical models and theoretical constructs often underpin, relate to and/or inform various determinants and correlates, and behaviour change techniques (Michie, et al., 2013; Choi, et al., 2017; Conner and Norman, 2017; Rhodes, et al., 2017; Michie, et al., 2018a; Rhodes, McEwan and Rebar, 2019; Biddle, et al., 2021). Explicitly reporting on the incorporation of theories, determinants and correlates, and behaviour change techniques is important for advancing the knowledge base, contributing to the growing understanding of what demonstrates efficacy and effectiveness, drawing comparisons between studies, as well as informing the design of future physical activity behaviour change interventions (Michie, et al., 2015; Taj, Klein and van Halteren, 2019). Theories, determinants and correlates, and techniques commonly utilised in the design of health

promotion behaviour change interventions for physical activity at the individual and interpersonal socioecological levels are covered in the following Subsections 3.5.1, 3.5.2 and 3.5.3, respectively.

### 3.5.1 Health Behaviour Change Theory for Physical Activity Behaviour Change Interventions at the Dual Intra-Interpersonal Socioecological Levels

*Theories, theoretical models and theoretical constructs* can be used for grounding the general design and objectives of an intervention and for informing the behavioural mechanisms incorporated into the intervention's component structure (Gourlan, et al, 2016; Conner and Norman, 2015; Gourlan, et al, 2016; Rhodes, et al., 2017; Rhodes, McEwan and Rebar, 2019; Taj, Klein and van Halteren, 2019; Rubinelli and Diviani, 2020). Physical activity behaviour change interventions based on and informed by appropriate evidence-based theory are more likely to succeed in improving individuals' physical activity engagements than those that are atheoretical or without an explicit theoretical foundation (Davis, et al., 2015; Gourlan, et al, 2016; Howlett, 2018; Hagger and Weed, 2019; Klonoff, 2019; O'Dwyer, et al., 2019; Zhang, et al., 2020). Despite the sizeable advocacy for theory in designing physical activity behaviour change interventions, some studies argue that the effectiveness of theoretical and atheoretical interventions are mixed or inconsistent (Prestwich, et al., 2014), while others claim that there is insufficient or no evidence to demonstrate that theory-based or theory-informed interventions are genuinely effective in real world settings (Hagger and Weed, 2019). Reports on mixed findings reveal issues associated with the incomplete utilisation of theory, inconsistent use of terminology, poor explicit reporting of theory, poor explanations for the links between theory and mechanisms of change, and comparisons or conclusions drawn without consideration for confounding variables (Michie, et al., 2015; Prestwich, Webb and Conner, 2015; Atkin, et al., 2016; O'Dwyer, et al., 2019). Arguments on the lack of evidence for theory effectiveness contend that study findings reporting on effectiveness mistakenly misuse the term to convey results of efficacy, and instead call for a paradigm shift that focuses on social practice disruption (Hagger and Weed, 2019). These arguments do, however, recognise the important role for behavioural theory on the individual level (Hagger and Weed, 2019), but tend to favour larger-scale socioecological perspectives that emphasise policy, legislative and societal level intervention over individual and interpersonal level intervention. Sneihotta, et al. (2018, p.e396) describes this narrative as "a false dichotomy", explaining that individuals are at the "heart" of and "central" to the socioecological system, and that if the focus on the system is at

the expense of individuals, then the primary objective to promote and effect health behaviour change in people is essentially counterproductive.

While research into the effectiveness, expansion and advancement of theory in the context of physical activity behaviour change intervention design and development remains ongoing (Howlett, 2018; O'Dwyer, et al., 2019; Zhang, et al., 2020), several behavioural change theories and theoretical models are evidenced to positively influence physical activity engagement on individual and interpersonal levels. These include, namely: (1) *theory of reasoned action (TRA)* and *theory of planned behaviour (TPB)*; (2) *the health belief model (HBM)*; (3) *social cognitive theory (SCT)*; (4) *self-determination theory (SDT)*; (5) *self-regulation theory* and *goal setting theory*; (6) *protection motivation theory (PMT)*; (7) *the transtheoretical model (TTM)*; and (8) *the health action process approach (HAPA)*. At the end of the subsection, Table 3.3 provides a summary outline of these theories and their key constructs.

The ten theories (under eight subheadings) covered in this subsection operate primarily at the individual level, but play a role in influencing peoples' interpersonal engagements and social interactions (such as SCT) (Glanz, Rimer and Viswanath, 2015). For example, a person's self-concept can influence their engagement with physical activity related groups, such as running groups, where social interactions and social support structures play a key role in learning about and motivating running behaviour. Although individual-level theories are often criticised for not being appropriate for expansion to large-scale organisational, community, societal and supranational levels, individual-level theories do complement and are frequently combined with the socioecological approach (Wingood and DiClemente 2019). Moreover, many studies demonstrate the effectiveness of individual and interpersonal theories in promoting physical activity behaviour change (Gourlan, et al., 2016; Howlett, 2018; Rhodes, McEwan and Rebar, 2019; Rhodes, et al., 2020; Biddle, et al., 2021). Notably, the theories covered are not exhaustive, do not include model illustrations, and do not elaborate extensively on each theory's strengths and criticisms. A more detailed review of theories of physical activity behaviour change, including dual process frameworks, can be referred to in Rhodes, McEwan and Rebar (2019), and a broader review of 80 behaviour change theories can be referred to in Davis, et al. (2015). The purpose of this subsection is to provide an overview of prominent theories in physical activity behaviour change intervention design literature, and to demonstrate the researcher's general understanding of the key theories, theoretical models and theoretical constructs in this domain of study.

***Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB)***

The *theory of reasoned action (TRA)* proposes that an individual's behaviour, such as physical activity, is best predicted by their intention to perform the behaviour, based on two cognitive variables, namely their 'attitudes' and 'subjective norms' (Fishbein and Ajzen, 1975). Attitudes are viewed as function of behavioural beliefs (beliefs that performing a particular behaviour will lead to certain outcomes) and their evaluative aspects (the evaluation of those outcomes) (Ajzen and Fishbein, 2000). Subjective norms are viewed as a function of normative beliefs (beliefs that a specific individual has regarding whether or not they should perform a particular behaviour) and motivations to comply (the extent to which, in general, an individual wants to do what the referent wants them to do) (Ajzen and Fishbein, 2000). An underlying assumption of the TRA is that people routinely consider the consequences of their behaviours prior to engaging with these behaviours (Raingruber, 2017). Criticisms of TRA argue that not all behaviours are necessarily under an individual's control and that it fails to consider external environmental factors and the role of emotion in behaviour change (Raingruber, 2017). Another critique concerns the measuring of the TRA's constructs and disparities identified in their implementation as behavioural change mechanisms in interventions (Buchan, et al., 2012). Despite these criticisms, the TRA has shown to demonstrate success when employed in the design of physical activity behaviour change interventions (Webb, et al., 2010; Angus, et al., 2013; Young, et al., 2014; Rhodes and Yao, 2015; Knittle, et al., 2018; Biddle, et al., 2021).

The *theory of planned behaviour (TPB)* then expanded on the TRA through the inclusion of the construct for 'perceived behavioural control', which refers to the ease or difficulty associated with an individual's views in changing their physical activity behaviour (Ajzen, 1991). This construct accounts for times when individuals do not possess conscious control over their actions, and when they intend to carry out a specific behaviour but lack confidence or control (Ajzen, 1991). The three key constructs of TPB that influence behavioural intent include (1) the individual's attitude towards a particular behaviour, (2) the individual's evaluation of how important significant others (such as a partner or family member) consider the behaviour to be (subjective norms); and (3) the degree of perceived behavioural control of the perceived ease/difficulty associated with executing behavioural change (Raingruber, 2017). Similarly to the TRA, the TPB is critiqued for its disregard for external environmental factors and the role of emotion in behaviour change (Raingruber, 2017) as well the measuring of its constructs and disparities identified in their implementation as behavioural change mechanisms in interventions (Buchan, et al., 2012). Despite these criticisms, the TPB has shown to

demonstrate success when employed in the design of physical activity behaviour change interventions (Webb, et al., 2010; Buchan, et al., 2012; Gourlan, et al, 2016; Knittle, et al., 2018).

### *The Health Belief Model (HBM)*

The *health belief model (HBM)* theorises that people's beliefs about whether they are at risk for a NCD or health issue, and their perceptions of the expected benefits of taking action to avoid it, influences their readiness to take action and change their behaviour (Becker, 1974; Janz and Becker, 1984). When first proposed, the HBM included four constructs: (1) perceived susceptibility (an individual's subjective assessment of their risk for developing a condition); (2) perceived severity (the seriousness of the condition and its consequences); (3) perceived barriers (obstacles that interfere with and facilitate the adoption of a behaviour, such as inconvenience, time and side effects); and (4) perceived costs of performing a behaviour or adhering to an intervention (Janz and Becker, 1984; Abraham and Sheeran, 2015). Later on, the HBM was extended to include people's consideration for symptoms and illness, and compliance with health professional directives. Constructs added to the HBM include: demographic variables (such as age, race and biological sex); psychosociological variables (such as socioeconomic status and personality); perceived self-efficacy (an individual's belief about their ability to adopt a behaviour); cues to action (factors that instigate promotive and preventative health, such as information); perceived benefits; motivation; perceived behavioural control; and perceived threat (Abraham and Sheeran, 2015).

Criticisms of the HBM argue that not all health behaviour is based on rational or conscious choice, and that the model focuses on negative factors without consideration for positive motivations that prompt health behaviours (Raingruber, 2017). While these criticisms are justified, the HBM and several of its constructs have shown to be effective when incorporated in the design of physical activity behaviour change interventions (Angus, et al., 2013; Abdi, et al., 2015; Taj, Klein and van Halteren, 2019). The HBM has also be expanded to the physical activity domain in particular, referred to as the Health Belief Model in Physical Activity (HBMPA) (Yen and Li, 2019), and has demonstrated effectiveness in informing the design of physical activity behaviour change interventions (Huang, et al., 2020).

### *Social Cognitive Theory (SCT)*

*Social cognitive theory (SCT)*, also referred to social learning theory (SLT), proposes that behaviour is learned through observation, imitation and positive reinforcement (Bandura, 1977;

1989; 1999). Learning is facilitated by role models, in that individuals re-enact behaviours they have observed directly or seen through media/technological sources (Bandura, 1977; 1999). Learning is also facilitated by observing and noticing the benefits of actions performed by other people (Bandura, 1977; 1999). According to SCT, behaviour is guided by expected consequences, and behaviour change is determined by personal, social, behavioural and environmental factors, each of which reciprocally influence one another (a conceptual also central to the socioecological model) (Glanz and Bishop, 2010). The six key concepts of SCT include: (1) reciprocal determinism (the individual, their behaviour and the environmental all influence one another); (2) behavioural capability (the knowledge and skills required to perform a behaviour); (3) expectations (anticipated outcomes); (4) self-efficacy (an individual's confidence in their ability to take action); (5) observational learning (learning by observing others); and (6) reinforcements (responses to behaviour that increase or decrease its likelihood of reoccurence) (Glanz, Rimer and Viswanath, 2015).

In terms of criticisms, it is proposed that SCT could be reconceptualised to position outcome expectations as both a source and consequence of self-efficacy beliefs, and that external socioecological factors be considered as both consequences and antecedents of self-efficacy (Beauchamp, Crawford and Jackson, 2018). While these criticisms are justified, the concept of self-efficacy has shown to be the strongest psychosocial construct of physical activity behaviour change, deeming it an undeniably key construct in promoting physical activity (Bauman, et al., 2012; Beauchamp, Crawford and Jackson, 2018; Rhodes, McEwan and Rebar, 2019). Overall, SCT is universally recognised as a key theory for informing the design of effective physical activity behaviour change interventions (Buchan, et al., 2012; Bully, et al.. 2015; Fanning, 2016; Gourlan, et al, 2016; Middelweerd, et al., 2018).

### *Self-Determination Theory (SDT)*

*Self-determination theory (SDT)* is a personality theory that includes behavioural factors and focuses on intrinsic motivations that drive individuals' choices (Deci and Ryan, 1985). Intrinsic motivation is the concept of engaging in an activity (such as running) out of personal interest and satisfaction, rather than being motivated by an external reward (such as money, peer pressure or the desire for external validation) (Deci and Ryan, 2008). Essentially, the theory suggests the individuals become self-determined when three basic needs are met (Deci and Ryan, 1985). These three needs are: (1) competence (an individual's ability to effectively deal with the environment and control the behavioural outcomes through mastery); (2) autonomy

(an individual's desire to have agency, make choices, initiate action and regulate their own behaviour); and (3) relatedness (an individual's desire to interact with, be connected to, and care for others) (Deci and Ryan, 2008; Raingruber, 2017). In addition, the three essential elements of SDT are that (1) humans inherently desire to master their inner drives and emotions, (2) humans possess an inherent tendency toward growth, development and integrated functioning, and that (3) optimal development and actions are inherent in humans but do not happen automatically (Deci and Ryan, 2008).

Criticisms concern SDT's binary view of intrinsic versus extrinsic motivation, arguing that individuals' can simultaneously be intrinsically and extrinsically motivated, as well as SDT's inconsideration for how other factors may influence an individual's perceived sense of competence and autonomy (Raingruber, 2017). Nevertheless, SDT is commonly identified as a valuable theory for informing the design of physical activity behaviour change interventions (Buchan, et al., 2012; Gourlan, et al, 2016; Rhodes, Kaushal and Quinlan, 2016; Nuojua, 2017). In designing physical activity behaviour change interventions, SDT has also demonstrated value when used in conjunction with motivational interviewing (Angus, et al., 2013; Abdi, et al., 2015; Nuojua, 2017).

***Self-Regulation Theory and Goal Setting Theory***

*Self-regulation theory* and *goal setting theory* are often tied to motivation when designing physical activity behaviour change interventions, and usually used in conjunction with constructs of SCT (Michie, et al., 2011; Teixeira, 2015; Kwasnicka, et al., 2017). *Self-regulation* refers to an individual's psychological and behavioural system of personal management that involves the process of guiding one's own self-generated thoughts, feelings and actions towards attaining certain personal goals (Teixeira, 2015). Concepts of self-regulation theory include standards, motivation, willpower and monitoring (Teixeira, 2015). In physical activity behaviour change intervention design, a frequently utilised example of a self-regulation technique is self-monitoring (Teixeira, 2015; Rhodes, et al., 2017). As suggested by the definition, a fundamental aspect of self-regulation theory is that human behaviour and behavioural change is directed towards achieving goals (Teixeira, 2015). *Goal setting* is a process that involves developing an action plan designed to motivate and guide an individual towards accomplishing a particular goal (Locke and Latham, 2002). A goal refers a future or desired result that an individual envisions, plans and commits to achieve (Locke and Latham, 2002). Goal setting theory takes into account several factors including goal commitment,

performance, self-efficacy, feedback, task complexity, motivation and satisfaction (Locke and Latham, 2002). Other theories and concepts sometimes employed in combination with self-regulation and goal setting theory include habit theory, the concept of small and incremental change, and the concept of cues (prompts) to action (Kwasnicka, et al., 2017). Both self-regulation and goal setting theory is shown to be effective when incorporated into the design of physical activity behaviour change interventions (Kwasnicka, et al., 2017; Walsh and Groarke, 2019).

***Protection Motivation Theory (PMT)***

Protection motivation theory (PMT) aims explain the cognitive mediation process of behavioural change in terms of threat and coping appraisal, and helps clarify fear appeals and how people cope with them (Rogers, 1975). In other words, it describes how individuals are motivated to react in a self-protective way towards a perceived health threat (Rogers, 1983). It proposes that people protect themselves based on four cognitive factors: (1) perceived severity of a threatening event or disease; (2) perceived probability of occurrence, or vulnerability; (3) efficacy of the recommended protective behaviour, and (4) perceived self-efficacy (Rogers, 1975; 1983). Individuals' protection motivation is viewed in terms of threat appraisal, which assesses the severity and seriousness of a situation (perceived severity and perceived vulnerability), and coping appraisal, which assesses how one responds to the situation (perceived response efficacy and perceived self-efficacy) (Rogers, 1975; 1983). Individuals' emotional state of fear arousal is also acknowledged to influence their attitudes and behavioural changes indirectly through the perceived severity of a situation (Rogers, 1975; 1983). The four cognitive factors are proposed to have significant association with intentions, which mediate their influence on behaviour performance; in other words, protection motivation is associated with behavioural intention (Rogers, 1975; 1983).

A critique of PMT is similar to many other individual-level theories, namely that it fails to account for external environmental factors that can also influence individuals' health behaviours (Plotnikoff and Trinh, 2010). Nevertheless, PMT is discussed in literature on health behaviour change theory in the physical activity domain (Gourlan, et al, 2016) and has shown to be modestly effective when incorporated in the design of physical activity behaviour change interventions (Plotnikoff and Trinh, 2010; Ruthig, 2016; Morowatisharifabad, et al., 2018).

### *The Transtheoretical Model (TTM)*

The *transtheoretical model (TTM)*, also referred to as the stages of change model (SCM), is an integrative biopsychosocial model that conceptualises individuals' willingness and intention to change their behaviour over six stages: (1) precontemplation, (2) contemplation, (3) preparation, (4) action, (5) maintenance, and (6) termination (Prochaska and DiClemente, 1982). The stages represent a variable temporal dimension of behaviour modification and individuals' transition through the stages is continuous, with each stage requiring certain tasks and decision-making processes (Prochaska and DiClemente, 1982). The adoption and maintenance of an individual's changes in physical activity behaviour are thus explained in the individual's passing through this series of sequential stages, each characterised by particular patterns of psychosocial and behavioural shifts (Prochaska and DiClemente, 1982). In the first precontemplation stage, individuals do not intend to take action in the foreseeable future (i.e. not within the next six months) (Prochaska and DiClemente, 1982). A lack of readiness may be characterised by an individual's unawareness, previous unsuccessful change attempts, resistance or a lack of acknowledgement or information about the behaviour and its consequences (Glanz, Rimer and Viswanath, 2015). In the second contemplation stage, individuals intend to change their behaviours within the next six months (Prochaska and DiClemente, 1982). A readiness for change is influenced by an acknowledgement and awareness of the pros/benefits and cons/costs of changing (Glanz, Rimer and Viswanath, 2015). Stage two can be associated with ambivalence and behavioural procrastination (Glanz, Rimer and Viswanath, 2015).

In the third preparation stage, individuals intend to take action in the immediate future (i.e. within the next month), have a plan of action and have already taken small behavioural steps (Prochaska and DiClemente, 1982). In the fourth action stage, individuals have made specific overt behavioural modifications in their lifestyles within the past six months (Prochaska and DiClemente, 1982). Action is not solely equated with observable action, but with certain criterion for sufficient risk reduction (Prochaska and DiClemente, 1982). In the fifth maintenance stage, individuals have made specific overt lifestyle behavioural modifications for over six months and are actively working at relapse prevention, but do not apply change processes as frequently as individuals in stage four (Prochaska and DiClemente, 1982). Based on self-efficacy and temptation, the maintenance stage can range six months to five years (Glanz, Rimer and Viswanath, 2015). Lastly, in the sixth termination stage, individuals are no longer tempted to relapse into old unhealthy behavioural coping patterns and are confident and

self-efficacious about their lifestyle behavioural modifications (Glanz, Rimer and Viswanath, 2015). Decisional balance, self-efficacy, temptation and ten processes of change mark four principle constructs that operate across the six stages to facilitate progress, reduce resistance and prevent relapse (Prochaska, Spring and Nigg, 2008).

In terms of criticisms, the TTM is critiqued for failing to consider the influence of external environmental factors on behaviour change, and the TTM stages are critiqued as arbitrary and not clearly distinct or sequential when observed in empirical study (Buchan, et al., 2012). The TTM has nonetheless been used in the design of physical activity behaviour change interventions, and has yielded positive and mixed effectiveness findings (Buchan, et al., 2012; Bully, et al., 2015; Gourlan, et al, 2016; Nuojua, 2017; Taj, Klein and van Halteren, 2019).

***The Health Action Process Approach (HAPA)***

The *health action process approach (HAPA)* is an integrated model and stage theory that improves on the explanatory value of the TTM, and aims to bridge the intention-behaviour gap with post-intentional influences and mediators, which other theories, such as TPB, SCT and PMT, do not address (Schwarzer, 1992; 2008; Howlett, 2018). The HAPA separates behaviour change into a motivation stage, where intentions are formulated, and a post-intentional volitional stage, where behaviour is enacted (Schwarzer, 1992). In the motivational stage, three factors proposed to influence intentions include (1) action/task self-efficacy; (2) outcome expectations; and (3) risk perceptions (Schwarzer, 1992; 2008). It is hypothesised that perceptions of risks associated with performing an unhealthy behaviour, or not performing a healthy behaviour, in combination with the belief that changing behaviour will beneficial, is likely to prompt individuals' intentions to change (Schwarzer, 2008). In the HAPA, self-efficacy is broken down into several types, with action self-efficacy (also referred to as task self-efficacy) being the most important factor in developing behavioural change intention; that is, a belief in oneself to perform a particular behaviour (Schwarzer, 1992; 2008). Once behavioural change intention is formed, two proposed mediators for translating intention into behaviour are action planning (planning for when, how and where behaviour will be performed) and coping planning (the anticipation of barriers and how these may be overcome using resources such as social support) (Schwarzer, 2008). Furthermore, the HAPA proposes that two other types of self-efficacy play a role in influencing action control and realised behaviour change, namely maintenance self-efficacy (helps individuals build confidence in

their ability to persist with behavioural change) and recovery self-efficacy (helps individuals re-start a behaviour after a forced interruption or lapse) (Schwarzer, 2008).

A critique of the HAPA is that although it has been tested experimentally in some physical activity contexts (for example, Rhodes and Yao, 2015), it has not been empirically tested very often as a basis for physical activity behaviour change interventions in randomised controlled trials (Howlett, 2018). Another critique is that the HAPA focuses predominantly on motivation, and fails to incorporate other internal processes (such as knowledge) and unconscious processes (such as identity, emotions and impulses) (Howlett, 2018). Nevertheless, the HAPA has been reported in literature on key physical activity behaviour change theories (Gourlan, et al, 2016), and its constructs (with the exception of risk perception) have shown to have significant effects when incorporated in the design of physical activity behaviour change interventions (Knittle, et al., 2018; Gholami, 2014; Zhang, et al., 2020).

*Table 3. 3: Summary of Intra-Interpersonal Health Behaviour Change Theories Commonly Employed in the Design of Physical Activity Behaviour Change Interventions [Source: Researcher's own construction, informed by sources provided in Subsection 3.5.1]*

| **Summary of Intra-Interpersonal Health Behaviour Change Theories Commonly Employed in the Design of Physical Activity Behaviour Change Interventions** | | |
|---|---|---|
| **Theory** | **Key Theoretical Constructs** | |
| **Theory of Reasoned Action (TRA)** | • Attitudes<br>• Subjective norms | • Behavioural intention |
| **Theory of Planned Behaviour (TPB)** | • Attitudes<br>• Subjective norms | • Perceived behavioural control<br>• Behavioural intention |
| **Health Belief Model (HBM)** | • Demographic variables<br>• Psychosociological variables<br>• Perceived susceptibility<br>• Perceived severity<br>• Perceived barriers<br>• Perceived costs | • Perceived self-efficacy<br>• Perceived benefits<br>• Cues to action<br>• Motivation<br>• Perceived behavioural control<br>• Perceived threat |
| **Social Cognitive Theory (SCT)** | • Personal factors<br>• Social factors<br>• Environmental factors<br>• Reciprocal determinism<br>• Behavioural factors | • Behavioural capability<br>• Outcome expectations<br>• Self-efficacy<br>• Observational learning<br>• Reinforcements |
| **Self-Determination Theory (SDT)** | • Competence<br>• Autonomy | • Relatedness |
| **Self-Regulation Theory** | • Self-regulation<br>• Behavioural intention<br>• Goals<br>• Standards | • Motivation<br>• Willpower<br>• Monitoring |

| | | |
|---|---|---|
| **Goal Setting Theory** | • Goals<br>• Goal commitment<br>• Task mastery | • Task complexity<br>• Performance<br>• Feedback |
| **Protection Motivation Theory (PMT)** | • Perceived severity<br>• Perceived vulnerability | • Perceived response efficacy<br>• Perceived self-efficacy |
| **Transtheoretical Model (TTM)** | • Precontemplation<br>• Contemplation<br>• Preparation | • Action<br>• Maintenance<br>• Termination |
| **Health Action Process Approach (HAPA)** | • Action/task self-efficacy<br>• Outcome expectations<br>• Risk perceptions<br>• Behavioural intention<br>• Action planning | • Coping planning<br>• Maintenance self-efficacy<br>• Recovery self-efficacy<br>• Action control<br>• Barriers and resources |

### 3.5.2 Health Promotion Behaviour Change Interventions for Physical Activity: Determinants and Correlates of Physical Activity at the Dual Intra-Interpersonal Socioecological Levels

*Determinants and correlates* provide an understanding of the constructs or factors that play a causal or associative role in explaining and predicting health behaviours (Bauman, et al., 2002; Rhodes, et al., 2017). In terms of intervention design, determinants and correlates are used to identify what mechanisms of peoples' behaviour can be targeted in order to affect behaviour change (Rhodes, et al., 2020; Biddle, et al., 2021). As stated in the introductory paragraph of Section 3.5, determinants and correlates are often related to or informed by theories or theoretical constructs of health behaviour change (such as those presented in Subsection 3.5.1) (Rhodes, McEwan and Rebar, 2019), and are also related to behaviour change techniques (Michie, et al., 2018a). Years of research has been conducted to investigate and identify the determinants and correlates that are evidenced to be effective at changing peoples' physical activity behaviour, and this research remains ongoing (Dishman, Sallis and Orenstein, 1985; Sherwood and Jeffery, 2000; Condello, et al., 2017; Rhodes, et al., 2020). Furthermore, determinants and correlates are often aligned with the socioecological levels of health promotion and are particularised in terms of various application contexts (Rhodes, McEwan and Rebar, 2019; Yen and Li, 2019). For example, identifying which determinants and correlates operate at individual and interpersonal levels within the physical activity domain (Bauman, et al., 2012). Determinants and correlates can, however, vary across demographic, psychological and biological characteristics, education levels, cultures, socioeconomic settings, geographical locations, general health status (healthy, unhealthy or medical condition-specific), age groupings and other factors (Rubinelli and Diviani, 2020). As a result, it is

acknowledged that the precise determinants and correlates of physical activity behaviour change remains partially inconclusive and at times inconsistent in terminological usage, generalisability and methodological quality (Craggs, et al., 2011; Stanley, et al., 2014; Atkin, et al., 2016; Condello, et al., 2017). Nevertheless, despite these challenges, meta-analyses and literature reviews in the physical activity behaviour change arena have been able to identify a basket of determinants and correlates that are common across population groups, deeming them reliable factors for understanding what influences change in peoples' physical activity behaviours (for example, Cortis, et al., 2017; Rhodes, et al., 2020).

The term 'determinants' should be used with caution since it implies a measurable cause-effect relationship between an individual's exposure to a factor and the resulting change on their physical activity behaviour (Bauman, et al., 2002; 2012). As a caveat, factors shown to demonstrate an associative and predictive relation with individual's behaviour change can be described in terms of probability, that is in terms of correlation, since an absolute cause-effect relationship may not always apply to all possible contexts (Bauman, et al., 2002; 2012; Rhodes, et al., 2017). Other ways to measure the relationships between factors and physical activity behaviour change include: mediators (that is, intervening variables necessary for the completion of a cause-effect relationship); moderators (that is, variables effecting the strength of a relationship between variables); and confounders (that is, variables associated with the behavioural outcome, but distort the strength of observed relationships) (Bauman, et al., 2002). Considering that this research project does not specifically focus on investigating factors and variables associated with physical activity behaviour change, only frequently reported determinants and correlates are covered in this subsection.

Figures 3.4 and 3.5 provide a summary of the common determinants and correlates identified as sufficiently effective (that is, moderately or highly effective) variables for physical activity behaviour change across all age groups. The summary does not intend to be exhaustive, but rather intends to provide a general overview of frequently reported effective individual and interpersonal level variables. The determinants and correlates outlined in Figures 3.4 and 3.5 were identified through a non-systematic comparative review on twenty-six (26) academic literature publications spanning years 1985 to 2020. Publications included systematic reviews, meta-analyses, literature reviews, academic books, discussion papers and primary empirical studies. The list of sources reviewed is provided in Appendix B. The summary of commonly identified determinants and correlates are classified as either *(1) individual-level factors*, comprising *'demographic and biological variables'*, *'psychological, cognitive and emotional*

*variables'* and *'behavioural variables'* (in Figure 3.4), or *(2) interpersonal-level factors*, covering *'social and sociocultural variables'* (in Figure 3.5).

As discussed in earlier subsections, while the importance of broader socioecological factors and their reciprocal deterministic influence on individual physical activity behaviour is acknowledged, this research study is delineated to the dual intra-interpersonal socioecological levels of health promotion (provided in justifications 1 to 6, Subsection 3.3.1). In addition, Figures 3.4 and 3.5 do not distinguish between whether the commonly reported variables classify as determinants or correlates. The reason being that publications often interchangeably referred to the same variables as either determinants or correlates, thus ambiguating whether the variables hold a cause-effect or associative relationship with physical activity behaviour change. Examples of such variables include 'self-efficacy', 'behavioural intention', 'perceived behavioural control'. Disambiguating between which variables are correctly classified as determinants and correlates does not align with the purpose of this summary review. Furthermore, no critical discussion is provided on the identified determinants and correlates, and no critical review is conducted on the study designs, methods or limitations of the reviewed publications. Neither of these critical reviews inform this particular study's research sub-questions, nor do they inform the design and development of the framework artefact contribution. The primary purpose of the summary provided in this subsection is to provide a high-level overview of the key determinants and correlates of physical activity behaviour change at the intra-interpersonal socioecological levels, and to demonstrate the researcher's general understanding of the factors evidenced to be sufficiently effective in changing individuals' physical activity behaviours. This understanding is necessary to demonstrate given the connections between determinants and correlates, health behaviour change theory, and behaviour change techniques, and more importantly, the importance of determinants and correlates in informing the design of effective physical activity behaviour change interventions (Atkin, et al., 2016; Michie, et al., 2018a; Rhodes, et al., 2020; Biddle, et al., 2021).

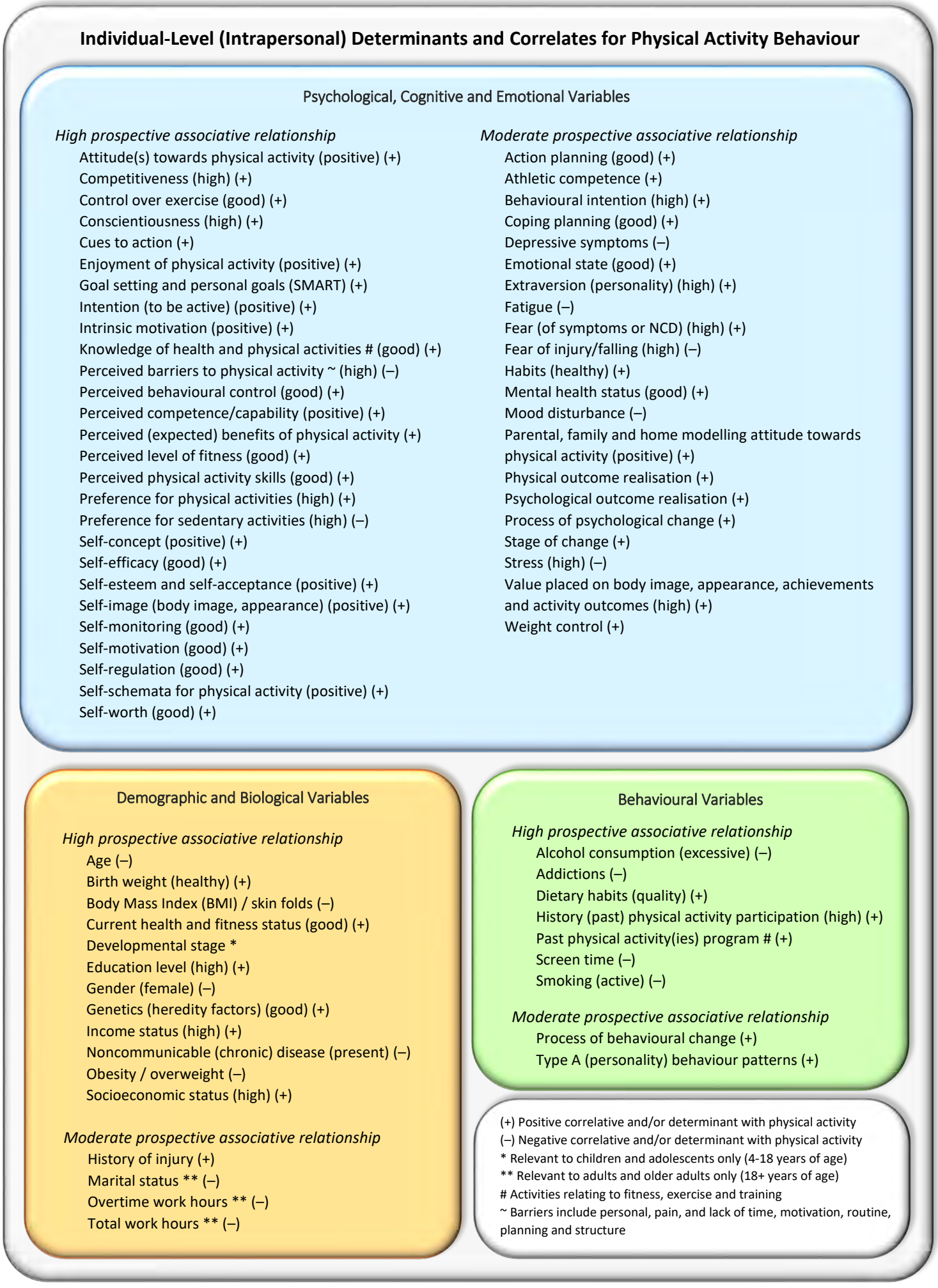



*Figure 3. 4: Individual-Level (Intrapersonal) Determinants and Correlates for Physical Activity Behaviour [Source: Researcher's own construction, informed by sources in Appendix B]*

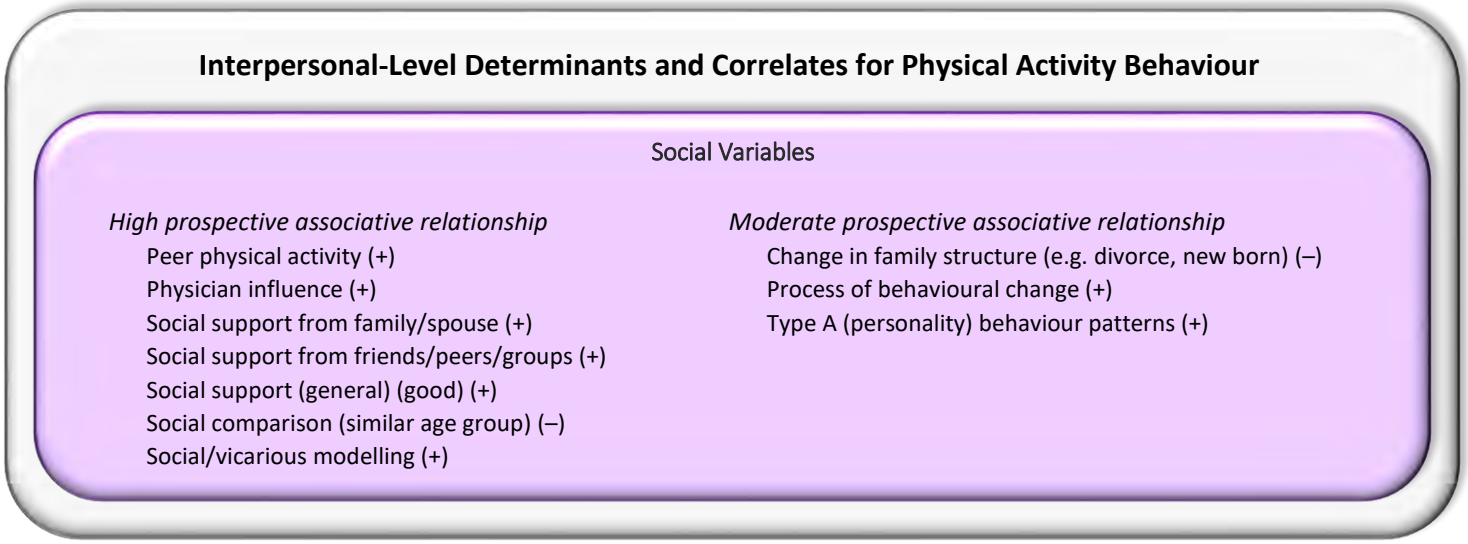



*Figure 3. 5: Interpersonal-Level Determinants and Correlates for Physical Activity Behaviour [Source: Researcher's own construction, informed by sources in review]*

### 3.5.3 Health Promotion Behaviour Change Interventions for Physical Activity: Behaviour Change Techniques

*Techniques*, generally referred to as behaviour change techniques (BCTs), are used as instruments within an intervention's component design structure to affect changes in individuals' behaviours (Michie, et al., 2008; Michie, et al., 2018). A BCT refers to the observable, replicable and irreducible "active ingredients" of an intervention; it is the smallest component in an intervention designed to alter or redirect causal processes that regulate human behaviour (Michie, et al., 2013, p.82). BCTs enable behaviour change; either by augmenting factors that facilitate behaviour change or by mitigating factors that inhibit behaviour change (Michie, et al., 2013). Augmenting, for example, can involve increasing an individual's beliefs in their capabilities, using the "Graded Tasks" BCT (Carey, et al., 2019, p.694). Mitigating, for example, can involve decreasing an individual's negative social influences, using the "Restructuring the Social Environment" BCT (Carey, et al., 2019, p.694).

Evidence-based BCTs, which are established through empirical investigation, can be mapped to theoretical constructs (such as those discussed in Subsection 3.5.1) and can be mapped to determinants and correlates (such as those discussed in Subsection 3.5.2) (Michie, et al., 2008). To clarify the distinction between determinants/correlates and techniques, Michie, et al. (2008) describe behavioural determinants/correlates in terms of *what* is being targeted, while techniques refer to *how* the determinants can be changed. A range of BCTs can be suitable to target certain determinants and correlates of physical activity behaviour at the dual intra-interpersonal level (Michie, et al., 2008; Michie, et al., 2013). When designing physical activity behaviour change interventions, BCTs can be used in isolation or in combination, and in a

variety of formats (Michie, et al., 2011). For BCTs to be effective, they need to target relevant mechanisms of action (Carey, et al., 2019). Mechanisms of action are conceptualised as a range of theoretical constructs, and can defined broadly as the processes through which a BCT affects an individual's behaviour (Michie, et al., 2018a). In other words, mechanisms of action are constructs specified in theories of health behaviour and health behaviour change that are identified as mediating intervention effects, such as "knowledge", "behavioural intention", "subjective norms" and "attitude towards behaviour" (Carey, et al., 2019, p.699). Within recent years, research into identifying the links between BCTs and the mechanisms of action they target, has been increasing and remains ongoing (Michie, et al., 2018a; Carey, et al., 2019; Johnston, et al., 2021).

The CALO-RE Taxonomy identifies forty (40) BCTs relevant to physical activity behaviour change interventions (Michie, et al., 2011). From these 40 BCTs, and depending on the targeted mechanisms of action, intervention designers can select and utilise one or more BCTs they deem applicable to incorporate in the intervention's component design (Hagger, Keatley and Chan, 2014). A list of the BCTs in the 40-item CALO-RE Taxonomy is provided in Table 3.4, along with definitions in terms of the physical activity domain. Notably, prior to the CALO-RE Taxonomy, a 26-item taxonomy was proposed (Abraham and Michie, 2008), and subsequent to the CALO-RE Taxonomy, a revised, hierarchically clustered 93-item BCT Taxonomy v1 was proposed (Michie, et al., 2013). The BCT Taxonomy v1, however, is appropriate to a broad range of modifiable health behaviours, including physical activity, healthy eating, smoking cessation, safe drinking, the prevention of sexually transmitted diseases, and more (Michie, et al., 2013), and therefore is not tailored solely to physical activity behaviour change. For this reason, Table 3.4 outlines the 40-item CALO-RE Taxonomy and not the 93-item BCT Taxonomy v1. Studies in physical activity behaviour change tend to use either of the two taxonomies, for example, CALO-RE in French, et al. (2014), Buckingham, et al. (2019) and Schroé, et al. (2020), and v1 in Howlett, et al. (2015) and Samdal, et al. (2017).

The purpose of Table 3.4 is to demonstrate the researcher's general understanding of the BCTs commonly available and utilised in the design of effective physical activity interventions. Whether BCTs are effective at targeting mechanisms of action that induce physical activity behaviour change can depend on how the techniques are operationalised (Michie, et al., 2008; Michie, et al., 2013; Direito, et al., 2018). While an individual's receptiveness and state of being, and various other complex variables can mediate, moderate or influence the effectiveness of BCTs, the operationalisation of BCTs into features within an intervention is

important when designing effective physical activity behaviour change interventions (Michie, et al., 2013). The operationalisation of BCTs into features of an intervention is influenced by the mode or platform through which the intervention is delivered (Michie, et al., 2008; Michie, et al., 2013; Direito, et al., 2018). For example, there are studies that have sought to investigate which BCTs are most effective at promoting physical activity behaviour change in terms of specific modes/platforms of delivery, such as mobile physical activity applications (apps) (Yang, Maher and Conroy, 2015; DeSmet, et al., 2019; Schroé, et al., 2020). Nevertheless, while operationalisation and mode/platform delivery play a role in the effectiveness of BCTs, there are several BCTs frequently reported as being effective at affecting physical activity behaviour change in individuals. Some of these BCTs include self-monitoring, goal setting (behaviour), goal setting (outcomes), social support, and providing feedback; most of which relate to self-regulation theory and goal setting theory (discussed in Subsection 3.5.1).

*Table 3. 4: CALO-RE Taxonomy: 40 Behaviour Change Techniques (BCTs) for Physical Activity [Source: Researcher's own construction, informed by Michie, et al. (2011) and Hagger, Keatley and Chan (2014)]*

| **CALO-RE Taxonomy: 40 Behaviour Change Techniques (BCTs) for Physical Activity** | | |
|---|---|---|
| **#** | **BCT** | **Definition of BCT in terms of Physical Activity** |
| 1. | Information provision (general) | Providing individual with general, non-specific information about physical activity and its possible outcomes. |
| 2. | Information provision (to the individual) | Providing individual with tailored specific information about physical activity and its outcomes, consequences, benefits and costs. |
| 3. | Information provision (others' approval) | Providing individual with information about what others might think about their physical activity (whether they like, approve or disapprove). |
| 4. | Information provision (others' behaviour) | Providing individual with information about what others commonly do with respect to physical activity (generally in relation to a group/population). |
| 5. | Goal setting (behaviour) | Encouraging individual to start or maintain behaviour change. Does not involve precise planning for behaviour performance or sequence. |
| 6. | Goal setting (outcomes) | Encouraging individual to set general goals that can be achieved through performance of the behaviour, but distinct from the behaviour itself. |
| 7. | Action planning | Detailed plans, including when and where actions will take place. |
| 8. | Identifying barriers/ Problem solving | Individual identifies possible barriers to performance and devise solutions to the possible challenges. |
| 9. | Setting graded tasks | The physical activity target behaviour is broken down into smaller, more manageable tasks, allowing for incremental progression towards goals. |
| 10. | Review of behavioural goals | Individual can review their successfully achieved goals. Contingencies and further plans can be made where goals are unmet. |
| 11. | Review of outcome goals | Individual can review previously set outcome goals, and has opportunity to revise plans to attain outcome goals. |
| 12. | Effort or progress contingent rewards | Individual is provided rewards or praise for attempts made towards achieving their goals. Not contingent on success, but on effort. |
| 13. | Successful behaviour contingent rewards | Individual is rewarded for successful physical activity performance. Reward may be material or verbal, but must relate to the target behaviour itself. |

| | | |
|---|---|---|
| 14. | Shaping | Graded contingent rewards for any form of progression towards completing the target behaviour. |
| 15. | Generalisation of target behaviour | Encouraging individual to generalise their successful physical activity performance to try in other instances, so prevent the behaviour from becoming situation-specific. |
| 16. | Self-monitoring of behaviour | Individual keeps a detailed record of their physical activity. |
| 17. | Self-monitoring of behavioural outcome | Individual keeps a detailed record of their measurable outcomes resulting from the physical activity behaviour change. |
| 18. | Focus on past success | Individual reflects on past successful physical activity engagements to increase their motivation to be active in the present and future. |
| 19. | Provide feedback on performance | Providing individual with feedback on their physical activity performance with the aim of motivating ongoing future physical activity engagement. |
| 20. | Informing when and where to perform the behaviour | Offering individual advice and ideas on when and where physical activity could be performed. |
| 21. | Instruction on how to perform the behaviour | Providing individual with instructions on how to effectively perform and engage in the physical activity. |
| 22. | Demonstrating behaviour | Showing individual how to accurately perform the physical activity, through verbal/auditory, visual or physical means. |
| 23. | Training to use prompts | Providing individual with cues that remind them to perform the physical activity. |
| 24. | Environmental restructuring | Individual is prompted to make changes in their surrounding environment, in order to facilitate physical activity behaviour changes. |
| 25. | Agreement of behavioural contract | A written/formal agreement between an individual and practitioner/party with respect to physical activity behaviour change. |
| 26. | Prompt practice | Prompting individual with reminders to rehearse and repeat physical activity, or behaviour that leads to physical activity engagement. |
| 27. | Follow-up prompts | Providing individual with prompts during physical activity engagement. |
| 28. | Facilitate social comparison | Encouraging individual to draw comparisons with others' physical activity behaviours to increase their motivation through modelling. |
| 29. | Plan social support | Prompting individual to elicit social support from people and close relations in order to facilitate successful completion of the physical activity. |
| 30. | Prompt identification as role model | Individual views themselves as a role model or example for physical activity behaviour. |
| 31. | Prompt anticipated regret | Inducing individual with expectations of shame, guilt or regret for failing to engage in the physical activity or failing to achieve the goal. |
| 32. | Fear arousal | Presenting individual with fear-inducing information in order to motivate physical activity behaviour change. |
| 33. | Prompt self-talk | Individual is encouraged to talk to themselves before and during the physical activity behaviour, for verbal encouragement, motivation and support. |
| 34. | Prompt use of imagery | Providing individual with visualization techniques and imagery to facilitate successful completion of the physical activity. |
| 35. | Relapse prevention | Encouraging individual to make plans to maintain physical activity behaviour change, and prevent relapse into prior inactive behavioural patterns. |
| 36. | Stress management | Encouraging individual to reduce stress and improve emotional control. |
| 37. | Motivational interviewing | A clinical method including specific techniques to prompt physical activity behavioural changes by minimising resistance and resolving ambivalence. |
| 38. | Time management | Assisting individual to manage their time effectively, making time for the physical activity behaviour to be performed. |
| 39. | Communication skills training | Improving communication skills in order to improve social interactions with others about physical activity behaviour. |
| 40. | Stimulate anticipation of future rewards | Encouraging individual to consider future rewards associated with outcomes. |

### 3.5.4 Challenges in the Design of Physical Activity Behaviour Change Interventions at the Dual Intra-Interpersonal Socioecological Levels of Health Promotion

There are various challenges that persist when it comes to the design of physical activity behaviour change interventions at the dual intra-interpersonal socioecological levels of intervention. Some of these challenges and knowledge gaps relate to the theory, determinants and correlates, and behaviour change techniques associated with physical activity behaviour change. As discussed in Subsections 3.5.1 to 3.5.3, research remains ongoing into (1) the theories, theoretical models and theoretical constructs, (2) the determinants and correlates, and (3) the behaviour change techniques, that are shown to demonstrate effectiveness in promoting physical activity behaviour change in individuals at the dual intra-interpersonal socioecological levels of intervention. Resolving these knowledge gaps is not a straightforward task, considering that humans are complex beings, whose behaviour is often difficult to reduce to theory, determinants/correlates and BCTs (Rhodes, McEwan and Rebar, 2019). The broader contextual, social, environmental, political and economic factors make the process of understanding, predicting, motivating and facilitating physical activity behaviour change in individuals even more challenging (Rhodes, McEwan and Rebar, 2019). Developing theories and identifying determinants/correlates and BCTs that are evidenced to promote physical activity is further complicated by the modes/platforms of intervention delivery and the operationalised design of intervention components (Direito, et al., 2018; Fulton, et al., 2018).

These challenges become more convoluted when studies display limitations such as methodological weaknesses, inconsistent terminology and poor reporting, which impacts the validity, credibility, generalisability and trustworthiness of findings in the knowledge base (Michie, et al., 2015; Cortis, et al., 2017). This presents as an issue because, if the knowledge base and published study findings are not trustworthy, the existing knowledge base will not be sufficiently helpful for informing improvements and advancements in the overall design and effectiveness of physical activity behaviour change interventions (Steinmo, et al., 2016; Cortis, et al., 2017). Well-designed and well-implemented studies that report mixed findings in terms of which theories, determinants/correlates and BCTs are effective at changing physical activity behaviour can only be informative to a certain extent (Prestwich, Webb and Conner, 2015), since the key to improving the design of physical activity behaviour change interventions relies on sound evidence for positive, and not mixed, effectiveness (Conner and Norman, 2017).

In light of the challenges associated with the design of intra-interpersonal behaviour change interventions, both in physical activity and other modifiable health behaviour domains, several approaches, guidelines and frameworks for informing the design of interventions have been proposed. These include, for example, the National Institute for Health and Care Excellence's (NICE) PH49 guidelines for individual-level behaviour change interventions (NICE, 2014), the Intervention Mapping (IM) approach (Bartholomew, et al., 2006; Bartholomew Eldredge, et al., 2016), the Theoretical Domains Framework (TDF), and the Behaviour Change Wheel (BCW) (Michie, van Stralen and West, 2011). In addition to these approaches, guidelines and frameworks, international knowledge hubs and projects, such as The Joint Programming Initiative's Determinants of Diet and Physical Activity (DEDIPAC) initiative (involving a network of 56 research groups), have been established to gain a better understanding of how individual psychological, behavioural and biological determinants and correlates influence physical activity behaviour (Brug, et al., 2017; Condello, et al., 2017; Cortis, et al., 2017; Aleksovska, et al., 2019). Furthermore, a recently published online publically accessible Theory and Technique Tool (TATT) has been made available, providing links between 74 BCTs and 26 mechanisms of action, for intervention designers, theorists and researchers to reference when designing health behaviour change interventions (Johnston, et al., 2021). Two other publically accessible and free digital tools made available are the BCT Taxonomy v1 (BCTTv1) mobile app (Norris, 2019) and the BCT Training Tool (Michie, 2021), which provide intervention designers with a resources for helping inform and support the design of health behaviour change interventions. While helpful and informative, neither of these digital resources consider modes/platforms of delivery, nor do they provide guidance in terms of how BCTs and mechanisms of action can be operationalised in interventions.

As conveyed before, linking the determinants/correlates to theory and mechanisms of action, and operationalising them as BCTs, whilst considering selected modes/platforms of delivery, presents knowledge gaps and challenges that remain ongoing; albeit there have been notable knowledge contributions and forward shifts in the last two decades (Taj, Klein and van Halteren, 2019). Within these shifts, there has been a progressive movement towards leveraging the opportunities technology offers as a powerful mode/platform for delivering physical activity behaviour change interventions; a digital health technology revolution that is changing the way interventions are designed and delivered to individuals across the globe (Gao and Lee, 2019). Gao and Lee (2019, p.1835) describe emerging technologies as bringing "exciting or even stunning opportunities for the promotion of PA [physical activity] and

health". Coupled with these innovative opportunities for technology-based physical activity behaviour change interventions, are challenges (Gao and Lee, 2019). Challenges are particularly in terms of how these digital interventions are designed, and the multi- and interdisciplinary collaborations needed to ensure that they are designed in ways that effectively promote physical activity and health (Blandford, et al., 2018; Sucala, et al., 2020). Taj, Klein and van Halteren's (2019, p.6) study on the last two decades of digital health behaviour change technology found there to be "a large gap in the process of designing digital technologies for health behaviour change". Moreover, they concluded that literature reporting on the design of digital health behaviour change intervention technology usually exhibit "weak theoretical grounding" and often "do not clearly report the different components" and the links between determinants, theories/mechanisms of action, and BCTs of such interventions, unveiling noticeable issues of design and a general lack of guidelines and approaches for designing digital health behaviour change intervention technology (Taj, Klein and van Halteren, 2019, p.6). These are some of challenges in the design of physical activity behaviour change interventions that need to be addressed if progress is to be made in the fight against the global physical inactivity and NCD pandemics.

## 3.6 Conclusion

This chapter contributes to answering the first research sub-question by providing an overview of the global health landscape in terms of the worldwide NCD pandemic, health promotion interventions and the importance of behaviour change interventions targeting physical activity as a leading modifiable health risk behaviour for NCDs. The socioecological model of health promotion was presented and the thesis's delineated focus on the dual intra-interpersonal levels was warranted with six justifications. Clarifications were provided on the main topics and key concepts of the thesis and its application context, namely, health, health promotion and physical activity. The last section of the chapter provided a discussion on the design of health promotion behaviour change interventions for physical activity at the dual intra-interpersonal socioecological levels. This section offered an overview of the role of theory, determinants and correlates, and behaviour change techniques in designing effective theory- and evidence-based health promotion behaviour change interventions for physical activity. Ten health behaviour theories commonly utilised in the design of intra-interpersonal physical activity behaviour change interventions were reviewed and their key constructs summarised in a table. Summary tables were also provided on the determinants and correlates, and behaviour change techniques, frequently reported in intra-interpersonal physical activity behaviour change intervention

literature. Before concluding the chapter, a brief overview of the challenges faced in the design of health promotion physical activity behaviour change interventions was presented, and acknowledgement was given of the opportunities and design challenges associated with the global shifts towards leveraging digital technology as a powerful and influential mode for delivering physical activity behaviour change interventions to individuals. Figure 3.6 provides a graphical overview of the funneled health landscape discussion in this chapter; laying the topic and context foundation for this research project (colours in Figure 3.6 do not denote specific meanings other than to distinguish each funnel layer; icons correspond to respective labels for each funnel layer).

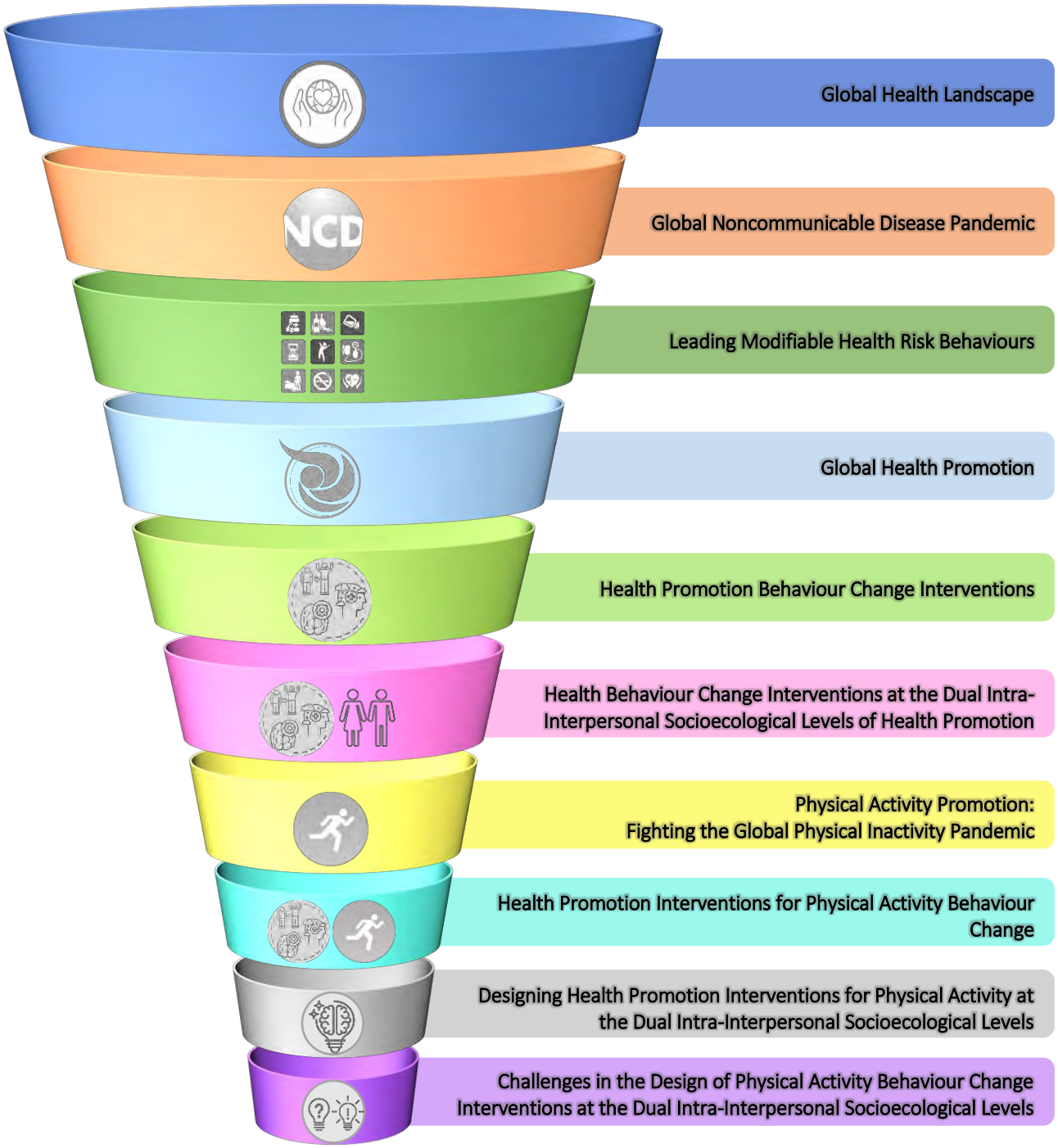



*Figure 3. 6: Funneled Overview of Health Landscape: Research Project Topic and Context Foundation [Source: Researcher's own construction]*

# Chapter 4

## Digital mHealth: Using Technology to Deliver Health Promotion Interventions for Physical Activity Behaviour Change

*The rapid expansion of technology promises to transform the behaviour science field by revolutionising the ways in which individuals can monitor and improve their health behaviours and ultimately their health.*

*– Sucala, et al. (2020, p.1538) –*



## 4.1 Introduction

Digital and mobile technological advancements are revolutionising the ways in which health promotion and health behaviour change interventions are delivered to individuals across the world, through devices and platforms such as websites, wearables and mobile applications (apps) (Blandford, 2019a; 2019b; Kickbusch, 2019; WHO, 2019; De Cocker, 2020; Blagden, et al., 2021). In the last ten to twenty years, research into the challenges and opportunities surrounding the digital health landscape and the use of mobile devices and apps for delivering health behaviour change interventions, such as physical activity promotion, has exploded; giving rise to a newly "emerging interdisciplinary field" of study (Taj, Klein and van Halteren, 2019, p.1). This chapter starts by introducing the digital health landscape, and positions the delineated research focus on the Consumer Health Informatics (CHI), mobile health (mHealth), and mHealth consumer app areas of specialised study. The next section elaborates on the use of mHealth consumer apps as a mode (platform) for delivering health behaviour change interventions at the dual intra-interpersonal socioecological levels, specifies the research scope to physical activity (health and fitness) apps, and discusses a few challenges, strengths and opportunities associated with mobile devices and health and fitness (physical activity) apps.

The subsequent section, divided into three subsections, provides a thorough and extensive discussion on the key challenges faced in the design of mHealth (physical activity) behaviour change intervention consumer apps targeting individuals at the dual intra-interpersonal socioecological levels of health promotion. The first subsection provides a discussion on the two broad perspectives of mHealth behaviour change intervention app design, namely the health behavioural sciences and information systems perspectives, and argues the need for collaboration and integration between these two perspectives. The second subsection discusses several key challenges associated with the design of mHealth (physical activity) behaviour change intervention apps, particularly in terms of theory, behaviour change techniques, persuasive systems design principles, effectiveness and approaches/processes. The third subsection is divided into two further subsections, providing a more detailed discussion on the challenges and opportunities associated specifically with approaches and processes for guiding the multi- and interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps. The first sub-subsection explains the similarities and differences between the approaches and processes that are typically used by the two broad perspectives, and reiterates and emphasises the ongoing need for "holistic" multi- and interdisciplinary approaches and processes that aim to bridge the divide between these two

perspectives (Van Gemert-Pijnen, et al., 2011, p.1; Wang, et al., 2019, p.1). The second sub-subsection provides a (preliminary) critical review of nine existing holistic multi- and interdisciplinary approaches, and discusses key strengths, limitations and challenges associated with these approaches, as well as knowledge gaps and opportunities for future research. This chapter, and particularly the arguments presented in section three, build to the main thesis problem addressed in this research project. The chapter then closes with a conclusion.

The main aim of this chapter, together with Chapter 3, is to provide further insight into the contextual landscape of the research and evidences the relevance and significance of the practical real-world design-orientated problem. As illustrated in Figure 4.1, this problem understanding falls within Step 1 ("awareness of problem") of the study's DSRM (outlined in Chapter 2). This chapter contributes to answering the first research sub-question: *"What is the role of mobile technology in delivering interventions for promoting physical activity behaviour change?"*, and the second research sub-question: *"What are the key challenges regarding the design, development and evaluation of mHealth behaviour change intervention apps for physical activity?"*.

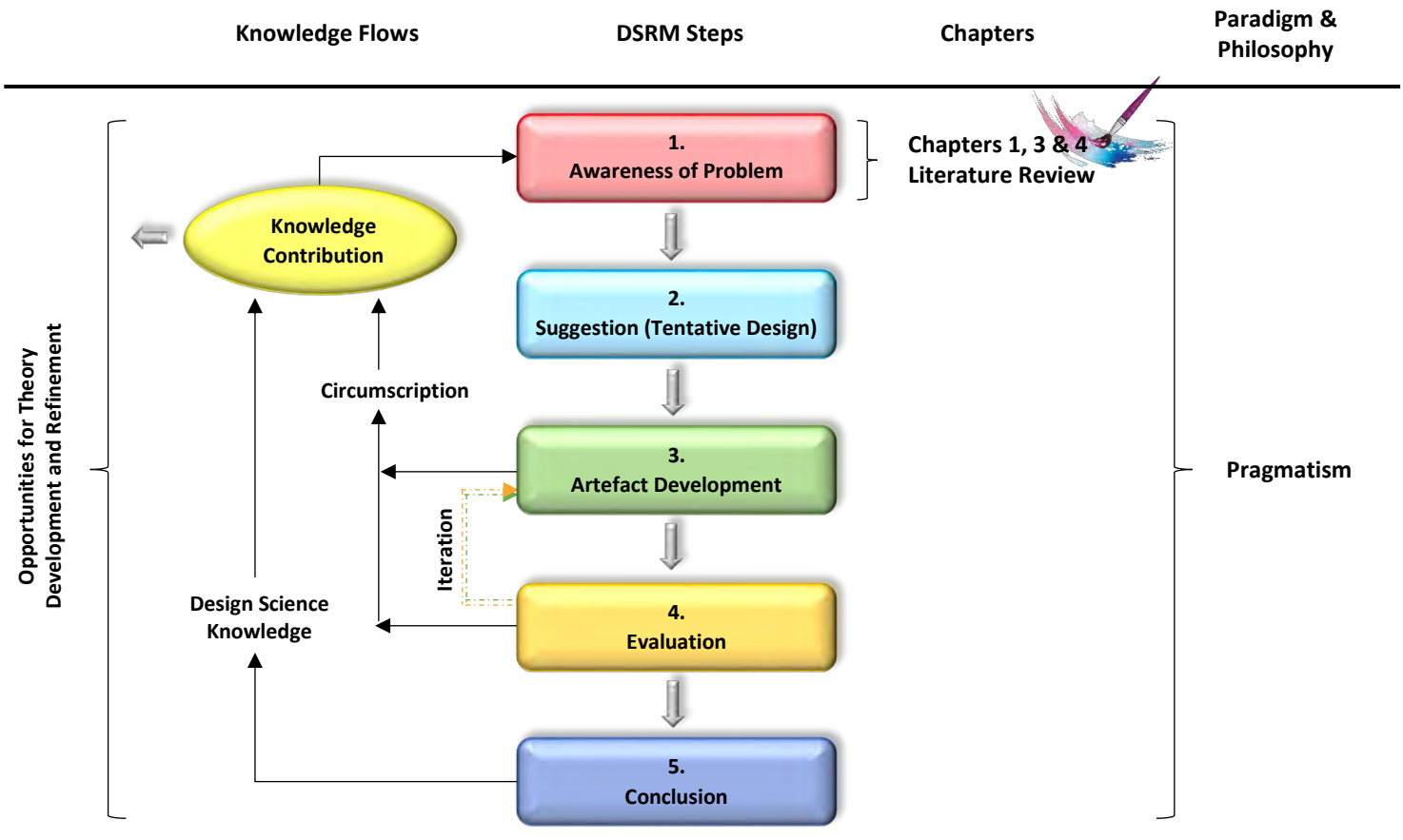



*Figure 4. 1: DSRM: Gaining Further Awareness and Understanding of Problem Space [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 4.2 The Digital Health Landscape: Consumer Health Informatics and mHealth Technology

Digital and mobile technology is revolutionising the way health behaviour change interventions are delivered to individuals across the globe (Lai, et al., 2017; Blandford, 2019b; Kickbusch, 2019; De Cocker, 2020; Chatterjee, et al., 2021). In the last two to three decades, a paradigm shift has been taking place within health promotion, NCD prevention/management and healthcare service delivery: a shift away from the traditional physician- (or institution-) centric health systems, towards consumer- (or patient-)centric health systems (Ferguson, 1995; Frank, 2000; Demiris, 2012; 2016; Edmunds, Hass and Holve, 2019). This paradigm shift reflects a progression towards a more globally interconnected, integrated and digitised health civilisation, referred to as the digital health revolution, where – through a sociotechnical perspective – people/society, technology and health all converge (Frank, 2000; Moller, et al., 2017). This digital health paradigm shift towards consumer-centric health promotion and NCD prevention complements the socioecological view (introduced in Chapter 3) of individuals as the central foci and core active agents in managing their own health and wellbeing (Stokols, 2018). Furthermore, the paradigm shift supports the modern concept of health (Huber, et al., 2011; 2016) and the socioecological notion for encouraging and empowering individuals to actively seek and share health information, engage in autonomous decision-making, and assume self-responsibility in making healthier lifestyle choices and health behavioural modifications (Faiola and Holden, 2017). Individuals, as consumers, are increasingly utilising digital and mobile technologies to access, track, monitor, store and share their personal health, physiological, medical and wellness data; enabling them to take charge of their own health and wellbeing (Laxman, Krishnan and Dhillon, 2015).

These shifts have expedited the growth of *Consumer Health Informatics (CHI)*, an area of study that focuses on the design, development and evaluation of technological tools and interfaces that emphasise understanding the perspectives, preferences and needs of health consumers as central and empowered individuals managing their own health and wellbeing (Flaherty, Hoffman-Goetz and Arocha, 2015; Faiola and Holden, 2017). Although coined in 1995 and popularised from 2000, the term CHI is yet to hold a widely accepted or uniform definition (Flaherty, Hoffman-Goetz and Arocha, 2015); although several definitions have been proposed (for example, Ferguson, 1995; Eysenbach, 2000; Keselman, et al., 2008; Gibbons, et al., 2009; Edmunds, Hass and Holve, 2019). Challenges with defining consensus terminology generally relate to the complex interdisciplinary nature of digital health and CHI, which requires

collaboration between information systems and technology, health psychologists, behavioural scientists, health professionals/specialists, human factors designers, and more (Van Gemert-Pijnen, et al., 2018). CHI solutions refer to any electronic tool, technology, digital device or digital application that is designed to interact directly with consumers, and provide them with individualised (personal) health information and assistance to better manage their health, with or without the presence of a healthcare professional (Gibbons, et al., 2009). Examples of CHI technologies include personal health records, home telehealth, precision medicine, and mobile health, amongst others (Demiris, 2016).

Consumer health informatics is a subfield of health informatics, which branches off the field of biomedical informatics (Eysenbach, 2000; Faiola and Holden, 2017). These fields rest on an underlying sociotechnical perspective, emphasising the synergistic convergence of people/society, technology and health (Faiola and Holden, 2017). Figure 4.2 provides an illustration of CHI's positioning as a subfield within the broader field of biomedical informatics, and its relation to the (sub)fields of bioinformatics, clinical informatics and public health informatics. Descriptions for these other (sub)fields is out of the main focus of this thesis discussion; however, to demonstrate the researcher's general understanding of these (sub)fields, their descriptions are provided in a tabularised format in Appendix C.1. Notably though, while Figure 4.2 provides a clear-cut picture of the (sub)field distinctions, in the real world, ongoing innovations and advancements in digital health blur the boundaries between these various (sub)fields, and several overlaps exist (Faiola and Holden, 2017; Nebeker, 2020). Nevertheless, Figure 4.2 aims to simplify these boundary complexities and position the thesis focus within the broader digital health revolution. Importantly, while the sociotechnical perspective is acknowledged in Figure 4.2, it does not frame the researcher's viewpoint in this research project; instead, other viewpoints are adopted (outlined in Chapter 2, Subsection 2.2.1).

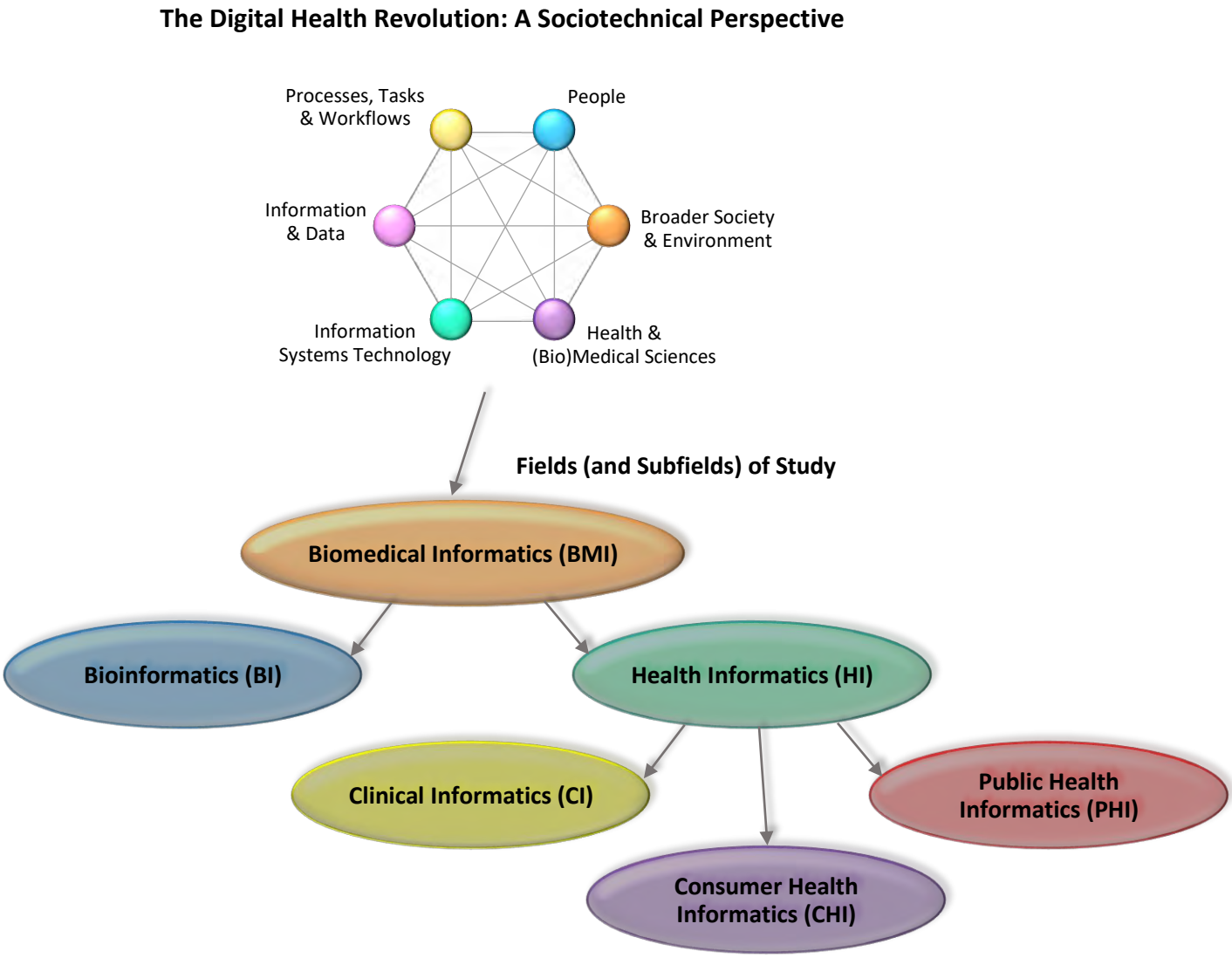



*Figure 4. 2: The Digital Health Revolution: Fields and Subfields of Study*
*[Source: Researcher's own construction, adapted from Faiola and Holden (2017)]*

Consumer health informatics and the broader digital health revolution have spurred diversified innovations in the development and ongoing advancement of digital health technologies. *Digital health technologies*, as a term, refers to the technological/digital tools or platforms that are leveraged as modes of delivery for carrying health information and interventions to individuals (Lucivero and Prainsack, 2015). Figure 4.3 provides a depiction of prominent digital health technologies utilised within the digital health arena. These technologies include: health information technology (HIT); healthcare systems (HS); electronic health (eHealth); personal health records (PHRs); electronic health records (EHRs); electronic medical records (EMRs); telehealth; telemedicine; Health 2.0; mHealth 2.0; social media; big data; games for health; the quantified self; sensors and wearables; mobile health; and health and wellness (lifestyle promotion) applications (Laxman, Krishnan and Dhillon, 2015; Wickramasinghe,

2019). Descriptions for all of these digital health technologies is out of scope of this thesis discussion; however, to demonstrate the researcher's understanding of these technologies, their descriptions are provided in a tabularised format in Appendix C.2. Likewise with Figure 4.2, in the real world, owing to the ongoing innovations and advancements in technology, the graphical circular boundary lines and positioning of the various digital health technologies in Figure 4.3 are not clear-cut or fixed, and consensus universal definitions remain inconclusive (Edmunds, Hass and Holve, 2019; Nebeker, 2020). Furthermore, the relative sizing of the circles in Figure 4.3 are not to scale and do not indicate prevalence or significance; the circle sizes are somewhat irrelevant – what is informative are the landscape overlaps, signifying the boundary complexities between various digital health technologies. Similarly to Figure 4.2, Figure 4.3 aims to simplify the boundary complexities and position the thesis focus.

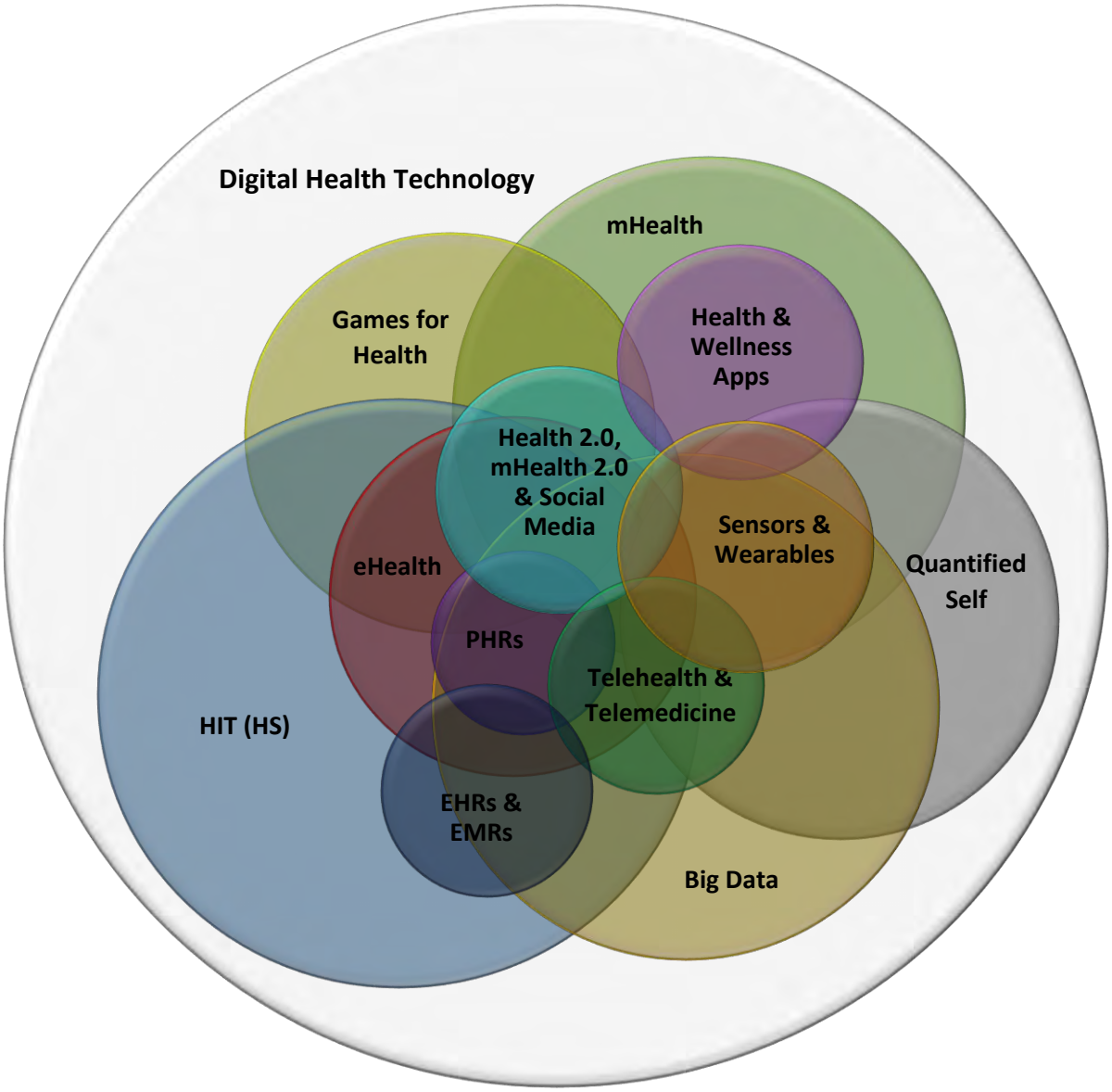



*Figure 4. 3: Digital Health Technology [Source: Researcher's own construction, adapted from IMT Innovation (2021)]*

This research project is scoped to mobile health (mHealth) as the digital health technology mode of delivery for health promotion behaviour change interventions. *mHealth* refers to the use of mobile computing and wireless communication technologies for NCD prevention/management, public health, medical and clinical service delivery, health and wellness promotion, and wellness planning, such as mobile phones, smartphones, tablets and personal digital assistants (WHO, 2018c). mHealth technologies are also used for health behaviour change interventions, clinical diagnosis and treatment, pharmaceutical drug adherence, health literacy/education, social connection, and more (Blandford, 2019b). Both consumers and healthcare professionals use mHealth technologies, although, depending on the purpose of the mHealth technology, the presence and engagement of a healthcare professional is not mandatory, such as the case with most health and wellness promotion applications (Demiris, 2016). mHealth technologies often capitalise on mobile device's core functions, such as voice and short messaging services, and on more complex functionalities, such as general pocket radio service (GPRS), global positioning system (GPS), third, fourth and fifth generation telecommunications (3G, 4G, 5G), Bluetooth technology, and inbuilt sensors (including the accelerometer and gyroscope) (Kao and Liebovitz, 2017).

mHealth technology offers a more cost-effective, accessible, convenient, real-time and efficient means for reaching more people, in comparison to traditional face-to-face settings (Knittle, et al., 2016; Kao and Liebovitz, 2017). In the face of rising global healthcare costs, limited resources, geographical dispersion, an insufficient supply of healthcare professionals, and ever-growing concerns for the global NCD pandemic and its associative links with modifiable health risk behaviours and premature mortality, mHealth technology is quickly becoming high on the agenda for the WHO and many countries' health strategies and plans (WHO, 2011; 2019). Examples of global strategies and plans include the WHO's *mHealth: New Horizons for Health Through Mobile Technologies* (WHO, 2011) and *Recommendations on Digital Interventions for Health System Strengthening* (WHO, 2019). Examples of regional and country specific strategies and plans include England's National Institute for Health and Care Excellence's *Behaviour Change: Digital and Mobile Health Interventions (NG183)* (NICE, 2020), the European Commission's *Green Paper on mHealth* (European Commission, 2014) and South Africa's *mHealth Strategy 2015-2019* (Department of Health, 2015). The power and influence of the mHealth market has caused it to skyrocket within the last decade, from a global value of US$ 718 million in 2011 to US$ 40.59 billion in 2019, and is estimated to reach US$ 310.37 billion by 2027 (Reports and Data, 2020).

Along with the opportunities and growth of mHealth technology, come challenges and obstacles (Kao and Liebovitz, 2017; Miah, Gammack and Hasan, 2017). These challenges are vast, ranging privacy and security; regulation and legislation; networking; infrastructure; data storage, processing and quality; health literacy; accessibility; acceptance and adoption; sustainability; efficacy and effectiveness; theory development; usability; and design (Laxman, Krishnan and Dhillon, 2015; Knittle, et al., 2016; Jusoh, 2017; Lai, et al., 2017; Van Velthoven, et al., 2018; Liew, et al., 2019; NICE, 2020). In terms of regulatory challenges, mHealth occupies a grey "ambiguous space" between the highly regulated medical domain (for example, medical and clinical applications) and the less regulated consumer market (for example, health and wellness promotion applications) (Lucivero and Prainsack, 2015, p.45); distinguished as high risk and low risk, respectively (Van Velthoven, et al., 2018).

Over and above are key challenges pertaining to underdeveloped and inappropriate theory and frameworks, poor methodological quality, inadequate guidelines and principles, and a paucity of approaches for guiding the design, development and evaluation of mHealth technology (Kowatsch, et al., 2019; Bendtsen, et al., 2020; Mussener, et al., 2020). These challenges stem from a paucity of multi- and interdisciplinary collaborations between the relevant parties necessary to produce effective mHealth technologies (Moller, et al., 2017; Blandford, et al., 2018; Peiris, Miranda and Mohr, 2018). To design, develop and evaluate efficacious and effective mHealth technologies, involvement from multiple diverse disciplines is required, including information systems, computer science, health and medical sciences, social sciences, health psychology, behavioural sciences, human computer interaction, user experience design (and its related disciplines), lifestyle-specific areas, and more (Knittle, et al., 2016; Blandford, 2019a; 2019b; Bendtsen, et al., 2020). Multi- and interdisciplinary collaborations can be challenging considering they often require fundamental "philosophical shifts in mindset" (Swan, 2012, p.94). Furthermore, as with other terminology in the digital health arena, a challenge is faced in that a consensus definition for mHealth has not been universally officialised (Cameron, Ramaprasad and Syn, 2017; Edmunds, Hass and Holve, 2019; Nebeker, 2020), and therefore is best defined and scoped in terms of its use and application in research studies.

In this thesis, focus is given specifically to *mHealth consumer applications (apps)*, as a type of mHealth technology. This implies a focus on consumer market mHealth apps, which aligns with the thesis delineation to the CHI subfield. Therefore, mHealth apps pertaining to the

medical domain, which require more regulatory, legislative, pharmaceutical, nursing, clinical and healthcare professional involvement, are excluded from this thesis scope. The use of the term mHealth consumer apps should also be further clarified in relation to this particular research project. mHealth consumer apps can be divided into two broad categories: (1) health and wellness (lifestyle promotion) mHealth consumer apps (such as health and fitness apps), and (2) NCD or chronic disease management mHealth consumer apps (such as diabetes and cardiovascular disease self-management apps) (Kao and Liebovitz, 2017). This research project focuses on the first category, health and wellness (lifestyle promotion) mHealth consumer apps – that is, apps intended to directly or indirectly maintain or improve healthy behaviours, quality of life and wellbeing of individuals (Lucivero and Prainsack, 2015); thus aligning with the health promotion and physical activity behavioural modification discussions presented in Chapter 3. It should also be noted that literature displays an interchangeable use of terminology when referring to mHealth consumer apps for health and wellness (lifestyle promotion). Some doctoral theses use the narrow device-specific term 'smartphone apps' (Fanning, 2016; McCallum, 2019), which (perhaps unintentionally) excludes tablet devices, while other doctoral theses use the broader term 'mHealth apps', which considers apps for both smartphone and tablet devices (Giunti, 2018; Haque, 2020). Considering that mHealth consumer apps for health and wellness (lifestyle promotion) can be downloaded and used on both smartphone and tablet devices, this thesis employs the latter, broader term *mHealth apps*, but with an implicit emphasis on consumer apps designed for smartphone and tablet devices.

## 4.3 mHealth Consumer Apps as a Mode for Delivering Health Behaviour Change Interventions at the Dual Intra-Interpersonal Socioecological Levels

This research is scoped to focus on mHealth consumer apps as a digital mode for delivering physical activity behaviour change interventions at the dual intra-interpersonal socioecological levels, which falls within the "*health and wellness (lifestyle promotion)*" category, and the "*health and fitness*" subcategory, of consumer market app stores (Google Play Store, 2021, p.1; Apple App Store, 2021, p.1). The two main consumer app markets for downloading health and fitness apps are the Google Play Store and the Apple App Store, supporting Android OS and iOS smartphones and tablet devices, respectively. Global downloads for health and fitness apps surged by 47% year-over-year in the second quarter of 2020, to over 656 million downloads, representing the largest increase ever for the second quarter (Sensor Tower, 2020).

The "explosive" growth of the health and fitness app market in 2020 is largely owing to the global novel severe acute respiratory syndrome coronavirus 2 (COVID-19) pandemic, which forced millions of people worldwide to turn to digital alternatives for supporting home workouts and exercises (Kim, et al., 2020, p.2; MoEngage and Apptopia, 2020, p.5). Within April and May 2020 alone, the health and fitness apps category generated US$ 328.5 million (Sensor Tower, 2020). In September 2020 alone, the revenues generated by the global leading health and fitness apps in the Google Play Store were *MyFitnessPal* (US$ 1.44 million), *Fitbit* (US$ 1.43 million), and *Strava* (US$ 1.15 million) – suggesting a highly lucrative market (Statista, 2021a). Some of the most popular health and fitness apps worldwide in 2020 and 2021 (on both Google Play and Apple App Stores) include: *MyFitnessPal*; *Fitbit*; *Strava; Adidas Running; Adidas Training; Nike Run Club; Nike Training Club; Sweat*; *Planet Fitness Workouts*; *Home Workout – No Equipment*; *WalkFit*: *Walking and Weight Loss*; *Better Me: Home Workouts and Diet*; *Fitness Coach*; *Muscle Booster*; *Weight Loss App for Women – Workout at Home*; *Peloton – At Home Fitness*; and *Six Pack in 30 Days – Abs Workout* (Apptopia, 2021). Many health and fitness consumer apps (including some above-mentioned) are particularised to specific types of physical activity, such as walking, running, cycling, HIIT (high-intensity interval training), circuit workouts, and strength/weight training (Vaquero, 2016).

These global top grossing and most popular health and fitness consumer apps are generally designed to be downloaded on smartphone and tablet devices. To clarify terminology, a *smartphone* is a palm-size handheld touchscreen personal mobile phone and communications device that comes with a built-in operating system (OS) (such as Android OS and iOS), an integrated mobile network and Wi-Fi connectivity, built-in sensors (such as an accelerometer and gyroscope), high definition cameras, and multimedia functionality, with text messaging and voice calling functionalities (Jee, 2017). A *tablet computer*, commonly referred to as a *tablet*, largely resembles a smartphone device, but it is usually comparably bigger in size, with screens measuring 18 cm or longer (Payne, et al., 2015; Jee, 2017). Both smartphone and tablet devices' operating systems support the downloading, installing and running of operating system software-specific applications (Kao and Liebovitz, 2017), referred to as third-party applications (Payne, et al., 2015). An *application*, commonly referred to as an *app*, is a small self-contained (third-party) software program designed for a specific purpose and functionality, and can be downloaded, for free or paid for, from various digital consumer marketplaces – generally Google Play Store for Android OS and Apple App Store for Apple iOS (Payne, et

al., 2015; MoEngage and Apptopia, 2020). The high volume of health and fitness app downloads parallels the global infiltration of smartphones and tablets. In 2020, there were 3.5 billion smartphone users worldwide, which translates to nearly 50% of the world's population owing a smartphone – demonstrating its widespread penetration and ever-increasing ubiquity (Statista, 2021b).

The popularity of smartphone/tablet devices and health and fitness apps as modes/platforms for delivering physical activity behaviour change interventions to the dual intra-interpersonal socioecological levels is owing to its strengths and opportunities that have increasingly been recognised and leveraged by both researchers/commercial companies and consumers (Bul, et al., 2020). In other words, the recognition of these devices and apps in society as powerful and "important delivery vehicle[s]" for physical activity behaviour change interventions is by virtue of concurrent high supply and high demand (Helf and Hlavacs, 2016, p.21). Why is this the case? Firstly, health and fitness apps make use of smartphones' and tablets' "always on", convenient, connected and cost-effective means of collecting, storing and sharing real-time context-aware data through GPS location tracking and other sensing technology (primarily an accelerometer, gyroscope, barometer and biometric sensors) (Harries, et al., 2013, p.17). Health and fitness apps can also be paired with other smart biometric sensors and wearable technologies (such as chest straps, smartwatches and foot pods) to gather and store a wealth vital sign, physical activity engagement, time-stamped and location-situated data with minimal interruption or obstruction to individuals (Knittle, et al., 2016). These digital and technological capabilities allow for health and fitness apps to track individuals' behaviours, habits, anthropometric data and vital signs over time, which can be used to generate trends and patterns that inform the delivery of personalised just-in-time and real-time information, feedback, reminders, nudges/cues and prompts tailored to suit individuals' goals, contexts, cognitions and behaviours (Jee, 2017). As smartphones/tablets become increasingly omnipresent and indispensable tools that people carry around and engage with on a daily basis, health and fitness apps that employ personalised, tailored, timely and contextual interventions become notably persuasive and effective when promoting physical activity behaviour change in individuals (Bondaronek, et al., 2018; Laranjo, et al., 2020).

Secondly, health and fitness apps make use of smartphones' and tablets' sensory-related interactive functionalities to provide a means for rich and complex data inputs and visual, auditory and haptic outputs and feedback (Jee, 2017). For example, some health and fitness

apps generate visual summary graphs and analytics of tracked anthropometric readings and physical activity engagements over a week or month(s), providing individuals with information they can easily interpret and make sense of when tracking and monitoring their physical activity progress and goals (Paul, et al., 2017). Thirdly, health and fitness apps make use of smartphones' and tablets' mobile network and Wi-Fi connectivity to effectively deliver physical activity behaviour change interventions to individuals across diverse demographic, geographic and socioeconomic groupings (De Cocker, 2020). As these devices and apps become more accessible, affordable and available to the global public, studies report them as useful tools for helping to bridge temporal barriers and geographical divides (Demiris, 2016; Kao and Liebovitz, 2017).

Fourthly, health and fitness apps have boomed in popularity because they are often linked with another recent digital phenomenon: social networking platforms, which also makes use of smartphones' and tablets' mobile network and Wi-Fi connectivity (Tong and Laranjo, 2018). Social media is increasingly being harnessed as a powerful complementary tool for delivering health promotion and physical activity behaviour change interventions to individuals and groups of individuals (Laranjo, et al., 2015; Tong, Coiera and Laranjo, 2018; Petersen, Prichard and Kemps, 2019). According to Kao and Liebovitz (2017), of the top health and fitness apps, over 65% connect to social media platforms, underscoring the importance of social networking/connectivity, social media and social support features in mHealth consumer app engagement and physical activity behaviour change intervention apps.

Recent studies have found social processes and mechanisms targeting social comparison, social participation, social support, social media groups, and social similarity and familiarity connections with other app users to be effective and "important to consider when designing physical activity interventions" (Tong, Coiera and Laranjo, 2018, p.1; Tong and Laranjo, 2018). These social processes correspond to the social (interpersonal) theories and theoretical constructs presented in Chapter 3, Subsection 3.5.1 (Petersen, Prichard and Kemps, 2019). These social processes often help foster individuals' self-efficacy, self-esteem, motivation and behavioural intention, and also provide a space where physical activity related information, knowledge, educational content and experience-based tips can be shared and exchanged between app and social networking platform users (Laranjo, et al., 2015). Yet, conversely, the integration of social networking platforms into health and fitness apps raises a number of issues and concerns. Studies have found some unintended consequences of social support structures

to include negative effects on individuals' self-efficacy and self-esteem, possible misperceptions of over-involvement or indebtedness, potential misunderstandings and conflict, unhealthy competition, and self-comparison-induced feelings of shame, inadequacy and defectiveness (Tong and Laranjo, 2018).

Overall, Millington (2014) sums up the fourth point, on the power and influence of social networking platforms being integrated into health and fitness apps, quite succinctly. He describes "health and fitness apps [as] directed towards both 'optimising' personal health and fortifying online communities [and social networks] – all while users move about their daily lives" (Millington, 2014, p.480). This fourth point, in addition to the first three points, demonstrates the power and potential of mobile (smartphone/tablet) devices and health and fitness apps as effective, far-reaching modes/platforms for delivering physical activity behaviour change interventions to consumers at the dual intra-interpersonal socioecological levels. Notably though, while mobile apps offer many strengths and opportunities as a powerful mode for delivering physical activity behaviour change interventions, there are also several challenges and obstacles that need to be addressed. These challenges and obstacles largely concern their design, effectiveness, integration of theory, and incorporation of behaviour change techniques (Conner and Norman, 2017; Blandford, 2019b; Kowatsch, et al., 2019; Milne-Ives, et al., 2020; Salwen-Deremer, et al., 2020; Schroé, et al., 2020).

## 4.4 Challenges in the Design of mHealth Behaviour Change Intervention Consumer Apps at the Dual Intra-Interpersonal Socioecological Levels

There are several challenges faced in the design of mHealth behaviour change intervention consumer apps targeting the dual intra-interpersonal socioecological levels. These mHealth app design challenges concern behaviour change interventions for physical activity as well as other modifiable health risk behaviours (such as dietary and nutrition intake, smoking cessation and more). Challenges associated with mHealth behaviour change intervention apps include, but are not limited to, concerns and issues regarding: design; advancing health behaviour change and technology-related theories and frameworks; behaviour change techniques; practice guidelines; contextual and situational awareness; and privacy and security (Michie, et al., 2017; Perski, et al., 2017; Salwen-Deremer, et al., 2020; Schroé, et al., 2020). Other issues include: a lack of effectiveness evidence for health and fitness consumer apps; barriers and obstacles around regulatory standards and policies; the voluminous "bewildering array" of health and

fitness consumer apps available for download; and a lack of intervention design reporting (Zhang, Zhang and Halstead-Nussloch, 2014, p.59; Michie, et al., 2015; Agarwal, et al., 2016; Milne-Ives, et al., 2020). Additional challenges concern: user experience; usability; user engagement; intervention adherence and effectiveness; sustainable adherence/usage; timeliness and accuracy of reminders and prompt interventions; persuasive design; ethical, philosophical, social and user perspective issues; and a paucity of approaches, processes and methods to design, development and evaluation (Van Gemert-Pijnen, et al., 2018; Haque, 2020; Hermsen, et al., 2020; Milne-Ives, et al., 2020).

This thesis focuses primarily on the *design* of mHealth intervention consumer apps for promoting physical activity behaviour change at the dual intra-interpersonal socioecological levels, and therefore aims to address challenges of a design nature. The term 'design', however, has no clear universal or all-encompassing definition (Ralph and Wand, 2009). It is a term that is broad in scope, loaded in meaning, flexible in interpretation, and is extensively fluid in its adaption and application to a multitudinous diversity of domains and contexts. For example, the term design is frequently used in domains spanning the creative arts, architecture, animation, fashion design, photography, graphic design, interior design, advertising, film-making, directing, the performing arts, urban design, industrial design, engineering design, web design, systems software design, and much more. Within these various domains and application contexts, the terminological use of 'design' assumes different meanings. In light of its extensive use and application, it is necessary to define the term design in general, and more importantly, to define the term in relation to this specific research project.

*Design*, generally speaking, is used as a blanket term for describing the conception, creation, construction and execution of a creative expression, action plan, or produced object artefact (Norman, 2013). The term design is commonly used as both a noun and a verb (Gregor and Jones, 2007; Ralph and Wand, 2009). Ralph and Ward (2009, p.108) propose the concept of design (as a *noun*) to be formally defined as: *"a specification of an object, manifested by some agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to some constraints"*. As a *verb*, the concept of design can be viewed and described as a *process* or *activity*, which refers *"to [the] creat[ion] of a design, in an environment (where the designers operate)"* (Gregor and Jones, 2007; Ralph and Ward, 2009, p.108).

In this research project, the term and concept of *design* is concerned with the conceptualisation, iterative development, formative testing and evaluation of health promotion behaviour change interventions delivered via mobile apps to individuals as consumers (as app users). In other words, the conceptualisation, development and evaluation of mHealth physical activity behaviour change intervention apps is viewed primarily through the lens of design, and therefore excludes other particular foci. Firstly, the use of the terms 'development' and 'evaluation' do not pertain to activities of coding and programming, or any of the like, which generally fall within the computer science discipline. Secondly, the use of the terms 'design', 'development' and 'evaluation' do not relate to challenges and issues of privacy and security, regulatory standards, policies and legislation, information architecture, networking and connectivity, et cetera. Instead, the term 'design' is orientated and delineated towards challenges and issues concerning health behaviour change and technology-related theories and frameworks, user experience, usability, app interaction and user engagement, behaviour change techniques, persuasive design, intervention/app effectiveness, and philosophical perspectives. These issues, through a design lens, are "wicked" in nature (Hevner and Chatterjee, 2010, p.11) and concern multiple disciplines – all of which are relevant to the main problem addressed in this thesis: there exists a paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps.

Clarity on how the above-mentioned design challenges and issues relate to the multi- and interdisciplinary design, development and evaluation of such apps is provided and elaborated on in the following three subsections. The first subsection discusses the two broad perspectives of mHealth behaviour change intervention app design, which are informed by different philosophical worldviews, yet require collaboration and integration for apps to be successful at promoting and empowering behaviour change in individuals. The second subsection discusses the key design challenges regarding the use and integration of theory, the incorporation of evidence-based behaviour change techniques, the application of persuasive systems design principles, and briefly touches on the use of multi- and interdisciplinary design, development and evaluation approaches and processes; all of which influence the effectiveness of mHealth (physical activity) behaviour change intervention apps. The third subsection is divided into two further subsections, providing a more detailed discussion on the challenges and opportunities associated with approaches and processes for guiding the multi- and interdisciplinary collaborative design, development and evaluation of mHealth (physical

activity) behaviour change intervention apps. The first sub-subsection explains the similarities and differences between the approaches and processes that are typically used by the two broad perspectives, and reiterates and emphasises the ongoing need for "holistic" multi- and inter disciplinary approaches and processes that aim to bridge the divide between these two perspectives (Wang, et al., 2019, p.1). The second sub-subsection provides a (preliminary) critical review of nine existing holistic multi- and interdisciplinary approaches, and discusses key strengths, limitations and challenges associated with these approaches, as well as knowledge gaps and opportunities for future research. The arguments presented in the third subsection build to and highlight the main thesis problem addressed in this research project.

### 4.4.1 Two Perspectives: The Need for Collaboration and Integration

The design of mHealth behaviour change intervention consumer apps can be viewed from two broad high-level perspectives, namely (1) a *health behavioural sciences perspective*, and (2) an *information systems perspective*. Both sides view the design of mHealth behaviour change intervention consumer apps in different ways, and are prone to have different points of interest. The differentiation between these two high-level perspectives in digital health intervention research has also been recognised and explicitly discussed in other studies such as Blandford, et al. (2018, p.1), where a distinction is made between a broadly defined "Health" side and "Human-Computer Interaction" side. The two health behavioural sciences and information systems perspectives tend to focus on different mHealth app design challenges and generally propose different solutions and contributions to resolve such challenges (Bul, et al., 2020). The two sides, generally speaking, hold different worldview orientations, knowledge and objectives, and utilise different practices, methods and approaches to mHealth app design, development and evaluation (Blandford, et al., 2018). Classifying the two perspectives presents a highly simplified and abstract differentiation, yet offers a conceptual clarification on the distinction between the two broad arenas – both of which are intrinsically relevant and important to the design of effective mHealth behaviour change intervention apps.

***The Health Behavioural Sciences Perspective***

The *health behavioural sciences perspective* primarily assumes a health psychology and health sciences orientation (Blandford, et al., 2018). In the case of this research, researchers and practitioners with a health behavioural sciences perspective are usually interested in challenges, issues and solutions pertaining to four areas of study when it comes to mHealth behaviour

change intervention consumer apps. Firstly, researchers and practitioners are concerned with the design, development, implementation and evaluation of the health behaviour change intervention itself, and the basket of intervention components, behaviour change techniques and mechanisms of action that make up the intervention (Yardley, et al., 2015a; Bartholomew Eldredge, et al., 2016; Little, Sillence and Joinson, 2017; Carey, et al., 2019). Secondly, researchers and practitioners (particularly in health psychology) are concerned with the adoption, application, testing and advancing of cognitive, attitudinal, social and behavioural psychology theories relevant to understanding and predicting health behaviour change (Moller, et al., 2017; Michie, et al., 2018a; Klonoff, 2019). Thirdly, researchers and practitioners are concerned with the determinants and correlates evidenced to be effective at influencing and changing peoples' health behaviours (Kok, et al., 2016; Rhodes, et al., 2020). Many researchers and practitioners are concerned with establishing and testing links between various determinants and correlates, health behaviour theories, mechanisms of action, and behaviour change techniques, and how these findings can be used to inform the design of more effective health behaviour change interventions (Conner and Norman, 2017; Direito, et al., 2018; Carey, et al., 2019; Hagger, et al., 2020). Fourthly, researchers and practitioners are concerned with intervention adherence and measuring the clinical and behavioural outcomes and effects of health behaviour change interventions; either in terms of physiological/anthropometric change or realised behavioural change (Howlett, 2018; Milne-Ives, et al., 2020). Measurement calculations and statistical analyses are generally conducted to determine the effectiveness of health behaviour change interventions – that is, whether the intervention as a whole is effective, or whether specific intervention components/techniques effect shifts in individuals' physiology and anthropometrics or realised behaviour change (Fanning, 2016; Schroé, et al., 2020).

The health behavioural sciences perspective is therefore usually associated with (sub)fields and specialisations ranging health psychology, health sciences, behavioural sciences, public health, health promotion, and specific domains of health behaviour (depending on the intervention target behaviour), such as physical activity, exercise sciences, nutrition sciences, alcohol addiction, et cetera (Bendtsen, et al., 2020). Although these areas of specialisation differ somewhat in knowledge, skills and expertise, they all fall under the broad health behavioural sciences perspective, and they all tend to employ theories, frameworks, models and methodologies that share a common thread: an integration of psychological cognitive, social and behavioural theories with theories of intervention development (Blandford, 2019a; Walsh and Groarke, 2019). In essence, the health behavioural sciences perspective is usually

interested in health behaviour change interventions, and the dynamics between humans (as individuals receiving the interventions) and interventions (including the intervention components, techniques and mechanisms of action) (Howlett, 2018). Researchers and practitioners who adopt the health behavioural sciences perspective typically employ approaches and processes that generally align with *intervention development* – that is, approaches and processes that guide the design, development and evaluation of health behaviour change interventions (Michie, van Stralen and West, 2011; Yardley, et al., 2015a; Bartholomew Eldredge, et al., 2016).

***The Information Systems Perspective***

The *information systems perspective* primarily assumes a socio-technological and systems orientation. In the case of this research, researchers and practitioners with an information systems perspective are usually interested in challenges, issues and solutions pertaining to four areas of study when it comes to mHealth behaviour change intervention consumer apps. Firstly, researchers and practitioners are concerned with the design, development, deployment, implementation and evaluation of the technology itself (that is, the mHealth app as a digital technology device) (Mohr, et al., 2014; Johnston, et al., 2015; Schnall, et al., 2016; Wilson, et al., 2018). Secondly, researchers and practitioners are concerned with humans' interactions with and use of the technology (that is, humans' interactions with and use of the mHealth app) (Baretta, Perski and Steca, 2019). This second area of study encompasses a range of foci, including human-computer interaction, user interface design, usability, user adoption, user acceptance, user engagement, mobile user experience, and more (Faiola and Holden, 2017; Kasali, et al., 2017; Blandford, et al., 2018; DeSmet, et al., 2019). Thirdly, researchers and practitioners are concerned with the persuasiveness of the technology (that is, the mHealth app's ability to persuade attitudinal and behavioural changes in app users) (Al Ayubi, et al., 2014; Langrial, 2014; Matthews, et al., 2016; Haque, 2020). Fourthly, researchers and practitioners are concerned with the effectiveness potential of the technology (that is, the mHealth app itself) (Blandford, et al., 2018).

The information systems perspective is therefore usually associated with (sub)fields and specialisations ranging human computer interaction, interaction design, user interface design, user experience design, human factors engineering, software systems design, user centred design, persuasive technology, persuasive systems design, and more (Al Ayubi, et al., 2014; Blandford, et al., 2018). Although these areas of specialisation differ somewhat in knowledge,

skills and expertise, they all fall under the broad information systems perspective, and they all tend to employ theories, frameworks, models and methodologies that share a common thread: an integration of psychological cognitive, social and behavioural theories with theories of technology/systems (Van Gemert-Pijnen, et al., 2011; Blandford, 2019a; Haque, 2020). In essence, the information systems perspective is usually interested in digital technologies/systems, and the dynamics between humans (as users) and digital technologies/systems (Kasali, et al., 2017). Researchers and practitioners who adopt the information systems perspective typically employ approaches and processes that generally align with the *systems (or software) development lifecycle* – that is, approaches and processes that guide the design, development and evaluation of technology/systems (Mummah, et al., 2016; Schnall, et al., 2016; Wilson, et al., 2018).

***The Need for Collaboration and Integration: Combining the Two Perspectives***

Recent years have seen a rise in calls for multi- and interdisciplinary collaborative efforts that essentially combine and integrate both broad perspectives into a "holistic" perspective (Van Gemert-Pijnen, et al., 2011, p.1; Wang, et al., 2019, p.1). From a holistic perspective, both the health behavioural sciences and information systems perspectives are relevant and necessary for designing effective mHealth behaviour change intervention apps. Blandford (2019b, p.75), for instance, underscores that "clearly both are important" and that a holistic approach should incorporate aspects from both perspectives. Blandford, et al. (2018, p.3) describe the two sides as offering "complementary perspectives", where several lessons can be learnt on both ends. An example of how these two perspectives differ, yet are both crucial to the holistic design of mHealth intervention apps for physical activity behaviour change, in particular, is provided in Box 4.1.

A holistic perspective presenting a multi- and interdisciplinary approach requires the involvement of experts from different disciplines working collaboratively as a team to improve the design, development and evaluation of mHealth behaviour change intervention apps (Murray, et al., 2016; Perski, et al., 2017; Van Gemert-Pijnen, et al., 2018; Mahmood, et al., 2019; Hermsen, et al., 2020). Smith, et al. (2017, p.109) highlight that software development processes for mHealth behaviour change intervention apps are "complex multidisciplinary projects" that require input from health psychologists, software designers and prospective app users, and that require reconciliation between health behavioural theories and software development processes. Bendtsen, et al. (2020, p.7) convey the same key message, explaining

that the development of mHealth lifestyle behaviour interventions is "complex" and requires multi- and interdisciplinary teams with "competence in technology, [health] behavioural science and subject-specific areas" such as physical activity, nutrition, smoking cessation, et cetera. Walsh and Groarke (2019, p.38, p.46) share the same sentiments, emphasising the need to "integrate [health] behavioural science with mobile (mHealth) technology to optimise health behaviour change interventions", and that a "strong multidisciplinary approach is required" with input from information systems designers and health psychologists working closely and collaboratively together to produce optimal solutions for health behaviour change. These sentiments are further echoed by other authors, such as Mohr, et al. (2014, p.1) who underscore the need to "bridge the fields of [health] behavioural science and technology", and Murray, et al. (2016, p.848) who stress that the mHealth behaviour change intervention app arena requires "fertile multidisciplinary collaborations that draw on insights and experience from multiple fields". Fundamentally, all of these arguments call for the combing and integrating of the two broad "complementary perspectives" (Blandford, et al., 2018, p.3) into one holistic perspective.

**Two Perspectives of mHealth Behaviour Change Intervention App Design: An Example in the Physical Activity Context**

Take for example a mHealth physical activity behaviour change intervention app designed to promote running in individuals (between ages 18 and 64 years). Real world running apps like this example – available for download in Google Play and Apple App Stores – include *Runkeeper*, *Map My Run*, *Adidas Running*, *Couch to 5K*, *Nike Run Club*, *Pumatrac* and *Zombies, Run!*.

From the health behavioural sciences perspective, the intervention is the primary interest. The chief focus is to design the running intervention and its components by incorporating BCTs that (1) are appropriate for the target audience (adults 18-64 years), and that (2) are evidenced to positively promote and effect individuals' running behaviour. Some evidence-based BCTs for running include goal setting (behaviour), goal setting (outcomes), self-monitoring, providing feedback and rewards. These BCTs target determinants and correlates, and mechanisms of action that drive processes of running behaviour change. In other words, these BCTs target theoretical constructs of health behaviour theories, including goal setting theory, self-regulation theory, social cognitive theory and self-efficacy theory. While the primary focus is on designing the intervention of the running app, the intervention will not be effective at promoting physical activity if the app is not designed appropriately.

From the information systems perspective, the app is the primary interest. The chief focus is to design the running app and its software features and functionalities. This generally involves focusing on the app's user interface design and PSD principles, which influence the adoption, acceptance, usability, user experience and persuasiveness of the running app. This also involves the process of translating and operationalising the intervention and its components and BCTs into software user interface design features in the app, which users will actively interact and engage with when using the running app. The way these app features are designed affects whether users continue to use, engage with and enjoy the running app, and hence affects the potential for the intervention to be effective in supporting and changing individuals' realised running behaviour. In other words, if the app is designed in a way that users deem unfriendly, and if the app exhibits poor usability and creates for negative user experiences, users are unlikely to continue using the app and the intervention app becomes ineffective.

Therefore, for the running app to be successful at promoting running behaviour change in individuals as users of the app, both the health behavioural sciences perspective and the information systems perspective need to be considered. Simply put, on the one hand, if the intervention is designed well, but it is not translated and operationalised properly into a well-designed usable, enjoyable and persuasive app, then the intervention is unlikely to be adhered to and will most likely be ineffective. On the other hand, if the app is designed well, but the intervention is poorly designed with BCTs are that inappropriate for influencing running physical activity behaviour change, then the app may be enjoyable to use, but it will unlikely be effective at promoting running behaviour. A holistic perspective that combines and integrates both perspectives is imperative for mHealth physical activity behaviour change intervention apps to be successful. This holistic perspective requires multi- and interdisciplinary collaboration between experts from both perspectives.



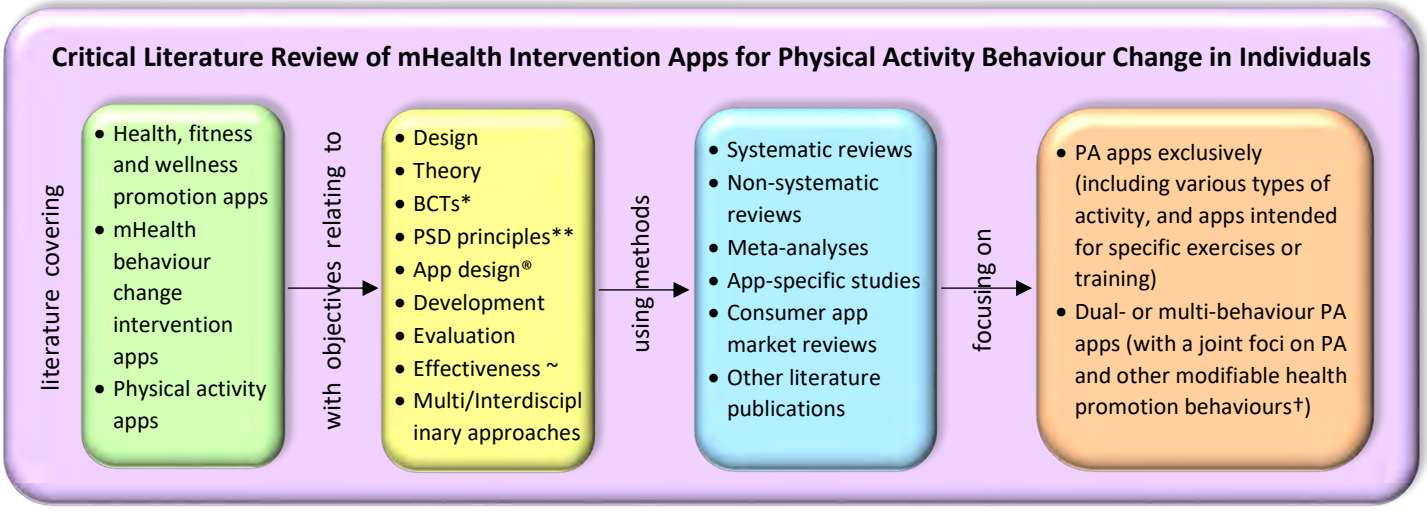
*Box 4. 1: Two Perspectives of mHealth Behaviour Change Intervention App Design: An Example in the Physical Activity Context [Source: Researcher's own construction]*

### 4.4.2 Design Related Challenges in mHealth Behaviour Change Intervention Consumer Apps at the Dual Intra-Interpersonal Socioecological Levels

With calls to combine and integrate the two broad, high-level health behavioural sciences and information systems perspectives into a holistic perspective that emphasises a multi- and interdisciplinary collaborative approach, come calls for ongoing research into addressing the associated challenges with multi- and interdisciplinary mHealth app project teamwork (Kostkova, 2015; Blandford, et al., 2018; Blandford, 2019a; 2019b). These challenges are generally associated with four themes of mHealth behaviour change intervention apps: (1) their *design* (subthemes: behaviour change techniques (BCTs), persuasive systems design (PSD) principles, usability, mobile user experience design, adoption/engagement usage; gamification); (2) their underpinning *theory*, (3) their *effectiveness*, and (4) the *multi- and interdisciplinary collaborative approaches and processes* that guide their design, development and evaluation. These four challenges are independent, yet also interrelated and interconnected in that they influence one another. They often arise due to differences in perspectives stemming from heterogeneous disciplinary backgrounds, which lead to misunderstandings and conflicts of interest between persons from both sides when attempting to work collaboratively during the mHealth behaviour change intervention consumer app design process (Carlile, 2002; 2004; Mohr, et al., 2014; Blandford, et al., 2018; Blandford, 2019a; 2019b; Bul, et al., 2020).

The design related challenges discussed in this subsection are informed by various literature, systematic reviews, meta-analyses, meta-regressions, empirical study findings, and the researcher's own thorough critical literature review of such published works. The discussion in this subsection covers the four themes in an interrelated and interwoven manner; given the complex nature and interdependencies between the four challenges, they cannot be discussed distinctly or disjointedly. For purposes of length, this extensive and lengthy 44 page critical review (covering the four challenge themes) is extracted to Appendix D. The main themes and points of interest are identified and discussed here in Subsection 4.4.2; derived through the researcher's cross-reviews and analyses from the comprehensive critical review. Some critical review findings from Appendix D also inform the points provided in the thesis's main body discussion in Subsection 4.4.3. In addition to the main themes and points of interest discussed in this subsection, Appendix D also thoroughly summarises and details the findings of studies, and additionally includes the names of specific research and commercial mHealth intervention apps specific to the context/domain of physical activity behaviour change. Figure 4.4 outlines

the key terms and area of foci used for conducting the critical literature review, which employed a hermeneutic literary search approach advocated for in information systems studies (Boell and Cecez-Kecmanovic, 2010; 2014).




** BCTs (Behaviour Change Techniques)*
*** PSD principles (Persuasive System Design principles)*
*® App design (including user interface design, user experience design, usability, aesthetics, engagement, gamification)*
*~ Effectiveness (including studies relating to efficacy, feasibility, adherence, usage, engagement and persuasiveness)*
*† Other modifiable health promotion behaviours include sedentary behaviour, diet and nutrition, weight loss/maintenance/gain, stress management, and sleep.*

*Figure 4. 4: Critical Literature Review of mHealth Intervention Apps for Physical Activity Behaviour Change in Individuals (at the Dual Intra-Interpersonal Socioecological Levels)*
*[Source: Researcher's own construction]*

There have been growing calls for the use and integration of intra-interpersonal evidence-based health behaviour change theories and behaviour change techniques (BCTs) in the design of mHealth behaviour change intervention apps, and physical activity consumer apps in particular (Yang, Maher and Conroy, 2015; Edwards, et al., 2016; Boulton, et al., 2019; DeSmet, et al., 2019; Dugas, Gao and Agarwal, 2020). Over recent years, arguments have increasingly emphasised that mHealth physical activity behaviour change intervention apps with solid theoretical bases are more effective than those lacking theoretical bases (Moller, et al., 2017; Wang, et al., 2017; Bohlen, et al., 2019; Klonoff, 2019; Marques, et al., 2020; Zhang, et al., 2020). Moller, et al. (2017) accentuate that more attention ought to be given to applying evidence-based theories and BCTs, and that when ignored, creates conditions under which interventions and their specific components may be less effective. Furthermore, studies have shown that mHealth physical activity apps are often characterised by a lack of adherence to health behaviour change theories (Cowan, et al., 2012; Baretta, et al., 2019; Truelove, et al.,

2020). Examples of evidence-based theories and BCTs for physical activity behaviour change in general were discussed in Chapter 3, Subsections 3.5.1 and 3.5.3, respectively. Identifying and applying evidence-based theories and BCTs makes for a more rapid, efficient and less costly design, development and evaluation process (Moller, et al., 2017). Wang, et al. (2017, p.4), for instance, highlight that "behavioural theories are not only used for understanding and predicting health behaviour, [but] more importantly, they are imperative to increase the effectiveness of designing mHealth interventions". In studies specifically focusing on mHealth physical activity behaviour change interventions apps, there are several prominent intra-interpersonal health behaviour change theories and BCTs that are recognised as demonstrating positive effects on changing individuals' physical activity behaviours; examples provided in Box 4.2, Box 4.3 and Box 4.4. The findings on these key evidence-based theories and BCTs for mHealth physical activity apps mirror the main theories and BCTs for physical activity behaviour change in general (discussed in Chapter 3).

**Intra-Interpersonal Health Behaviour Change Theories Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps**

- Social Cognitive Theory
- Theory of Reasoned Action
- Theory of Planned Behaviour
- Self-Efficacy Theory
- Protection Motivation Theory
- Self Determination Theory
- Self-Regulation Theory
- Health Belief Model
- Health Action Process Approach
- Goal Setting Theory
- Dual Process Theory of Persuasion
- Social Support Theory
- Transtheoretical Model (Stages of Change)
- Elaboration Likelihood Model

*Box 4. 2: Intra-Interpersonal Health Behaviour Change Theories Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps [Source: Researcher's own construction, informed by various studies]*

**Intra-Interpersonal Health Behaviour Change Theories Commonly Used in the Design of Physical Activity (PA) Apps: Examples**

**PA apps using Social Cognitive Theory:** *PersonA* (Al Ayubi, et al., 2014); *Balanced* (Duncan, et al., 2016); *BeWell24* (Buman, et al., 2016); *CityU Walk* (Wong and Kwok, 2016); *Active Team* (Edney, et al., 2017); *Runkeeper*, *Strava*, *Adidas*, *Adidas Training* and *Endomondo* (Ploumen, 2016).

**PA apps using Social Support theories and constructs:** *BeWell* (Rabbi, et al., 2011); *Cardio Trainer*, *Social Sport* (Weng, et al., 2013); *HealthyTogether* (Chen and Pu, 2014); *BikeTogether* (Chen and Lee, 2015); *iBurnCalories* (Khatri, 2015); *Pocket Yoga* (Ingber, 2015); *Ubersense* (Martin, Melnyk and Zimmerman, 2015); *iGo* (Haque, et al., 2016); *MyFitnessPal* (Zhao, Freeman and Li, 2016); *bActive* (Harries, et al., 2017); *Starfish* (Paul, et al., 2017); *Strava* (Smith and Treem, 2017); *Nike+ Running Club*, *Nike+ Training Club*, *Endomondo*, *Runkeeper*, *Everywhere Run*, *Everywhere Race*, *Fitocracy*, *Strava Cycling*, *Noom CardioTrainer* and *Nexercise* (Middelweerd, et al., 2014; op den Akker, 2014).

**PA apps using Self-Determination Theory:** *iGo* (Haque, et al., 2016) and *CityU Walk* (Wong and Kwok, 2016).

**PA apps using Self-Regulation Theory:** *MPTrain* and *TripleBeat* (op den Akker, 2014).

**PA apps using the Transtheoretical Model:** *UbiFit Garden* (Consolvo, et al., 2009); *ePass*, *eVIP*, *eSIYP* and *eTIYP* (Dute, Bemelmans and Breda, 2016).

**PA apps using Goal Setting Theory:** *Chick-Clique* (Toscos, et al., 2006; 2008); *Fish'n'Steps* (Lin, et al., 2006); *UbiFit Garden* (Consolvo, et al., 2009); *Accupedo-Pro Pedometer* (Glynn, et al., 2014); *iBurnCalories* (Khatri, 2015); *Starfish* (Paul, et al., 2017).

*Box 4. 3: Intra-Interpersonal Health Behaviour Change Theories Commonly Used in the Design of Physical Activity (PA) Apps: Examples [Source: Researcher's own construction, informed by various studies]*

**Behaviour Change Techniques (BCTs) Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps**

- Goal Setting (Behaviour)
- Goal Setting (Outcomes)
- Feedback on Behaviour
- Self-Monitoring of Behaviour
- Self-Monitoring of Outcome(s) of Behaviour
- Action Planning
- Demonstration of the Behaviour
- Shaping Knowledge
- Social Support
- Social Comparison
- Reward(s) (Outcome)
- Reward(s) (Behaviour)

*Box 4. 4: Behaviour Change Techniques (BCTs) Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps [Source: Researcher's own construction, informed by various studies]*

Despite the growing calls for the integration of evidence-based BCTs in physical activity apps, some studies reveal their limited presence in physical activity consumer apps available in the Google Play and Apple App Stores (that is, BCTs outside of those frequently identified in Box 4.4) (Conroy, Yang and Maher, 2014; Yang, Maher and Conroy, 2015; Bardus, et al., 2016; Edwards, et al., 2016; Direito, et al., 2018; Bondaronek, et al., 2018). Studies have also revealed that while some physical activity consumer apps adhere to evidence-based exercise guidelines and the WHO's physical activity recommendations (such as *Couch-to-5K*; *Sworkit Fitness*; *JEFIT Workout*; *StrongLifts 5x5*; *NFL Play*; *Zombies, Run!*), other apps do not (such as *Daily Ab Workout*; *Daily Butt Workout*; *Workout Trainer: Home Fitness Coach*) (Knight, et al., 2015; Modave, et al., 2015; Schoeppe, et al., 2017). Furthermore, regardless of the growing calls for the integration of evidence-based health behaviour change theories, some reviews reveal mixed findings for the use and application of theories and theoretical constructs as positively associated with the effectiveness of mHealth physical activity behaviour change intervention apps (Payne, et al., 2015; Kao, et al., 2017; Howlett, 2018; Salwen-Deremer, et al., 2020). Notably though, many of these studies acknowledge that mixed results are often due to certain issues. These include: the incomplete or fractional application of theories and theoretical constructs in mHealth physical activity apps; the use of outdated theories (which require advancement, extension and revision); the application of unsuitable theories (in relation to the app's objectives and target audience); and biased or poor quality reporting (Hekler, et al., 2016; Moller, et al., 2017; Bohlen, et al., 2019).

Poor reporting of evidence-based health behaviour change theories and BCTs has been met with international standardised reporting guidelines, including the WHO's *Mobile Health Evidence Reporting and Assessment (mERA) Checklist* (Agarwal, et al., 2016), two BCT taxonomies and a taxonomic method for reporting BCTs (Michie, et al., 2011; 2013; 2015), the *Template for Intervention Description and Replication (TIDieR)* checklist and guide (Hoffmann, et al., 2014), and the *CONSORT-EHEALTH Guidelines and Checklist* (Eysenbach, 2011). However, many studies and literature publications still fail to adhere to and apply these standardised reporting guidelines (Bohlen, et al., 2019; Taj, Klein and van Halteren, 2019; Fiedler, et al., 2020). Applying and reporting on evidence-based theories and BCTs that demonstrate effectiveness is important for growing and enriching the knowledge base, and accounting for what is known and unknown (Michie, et al., 2015; Conner and Norman, 2017; Bohlen, et al., 2019; Taj, Klein and van Halteren, 2019; Fiedler, et al., 2020). What is also challenging, though, is that for those who do adhere to the guidelines and clearly report on

what demonstrates effectiveness, many are reporting on dual- or multi-behaviour intervention apps, and not solely physical activity apps. In other words, the available knowledge base contains studies on mHealth behaviour change intervention apps that concurrently target physical activity along with other health promotion behaviours. For example, apps that simultaneously target physical activity and reducing sedentary behaviour (Duncan, et al., 2017), improving dietary and nutrition intake (Wang, et al., 2016), supporting weight loss/management/gain (Tang, et al., 2015), bettering stress management (Yu and Huang, 2020), and improving sleep (Duncan, et al., 2017). A literary pool of mixed behaviour-targeting mHealth app intervention findings can complicate identifying what works and what does not work for targeting physical activity behaviour change specifically when using mHealth app digital technology as a mode of intervention delivery. Nevertheless, clear reporting helps provide a roadmap for guiding how effective mHealth physical activity behaviour change intervention apps can be optimally designed, developed and evaluated, repeated more quickly across varying contexts, and helps prevent recurring mistakes (in both research and industry) (Hekler, et al., 2016; Moller, et al., 2017; Van Gemert-Pijnen, et al., 2018; Mahmood, et al., 2019).

Better reporting is also required to identify the optimal ways evidence-based theories (mechanisms of action) and BCTs can be "translated" (Middelweerd, et al., 2014, p.103; Sporrel, et al., 2021, p.2) and "operationalised" (Paul, et al., 2017, p.4; Perski, et al., 2017, p.254) into engaging and persuasive interactive mHealth app (user interface) design features. This is additionally needed in the reporting of persuasive systems design (PSD) principles, and how persuasive strategies can be optimally translated and "operationalised" into software design features in mHealth behaviour change intervention apps (Geuens, et al., 2016, p.167; Schoeppe, et al., 2017, p.89; Geuens, et al., 2019a, p. 351). The terms "translated" and "operationalised" essentially refer to the ways in which app designers convert theories/mechanisms of action, BCTs and PSD principles into app design features that are observable and interactive through the apps' user interface graphical displays, which ultimately affects the overall usability, acceptance/adoption, engagement and effectiveness of mHealth behaviour change intervention apps (Sporrel, et al., 2021). Concerns and challenges regarding translation and operationalisation generally stem from the information systems perspective, yet, regardless, the proper translation and operationalisation of theories, BCTs and PSD principles is "essential" for the development of mHealth behaviour change intervention apps (Taj, Klein and van Halteren, 2019, p.17).

Persuasive systems design (PSD) principles, informed by the Persuasive Systems Design Model (PSDM) (Oinas-Kukkonen and Harjumaa, 2009) which falls within the fields of persuasive technology and health behaviour change support systems, refer to specific strategies that intend to ethically persuade, influence and change humans' attitudes and behaviours towards a particular modifiable health behaviour (Sporrel, et al., 2021). Appendix E provides a broader discussion on the fields of fields of persuasive technology and persuasive systems design, to demonstrate the researcher's understanding of these areas of study. Appendix E also discusses these two fields in terms of mHealth intervention apps for physical activity behaviour change in particular. These two fields of study are not the sole focus in this research and hence are excluded from the main body thesis discussion and extracted into an appendix. However, there are key elements of the PSDM that are important to review in the main body of this discussion. In the PSDM, there are 28 PSD principles, classified across four categories (primary task support; dialogue support; system credibility support; and social support) (Oinas-Kukkonen and Harjumaa, 2009), which are often used in the design of effective mHealth physical activity behaviour change intervention apps (Matthews, et al., 2016; Paul, et al., 2017; Haque, 2020; Sporrel, et al., 2021). These PSD principles are outlined with descriptions and mHealth physical activity app examples in Table 4.1. In studies specifically focusing on mHealth physical activity behaviour change interventions apps, there are several influential and useful PSD principles that are recognised as demonstrating positive effects on changing individuals' physical activity related motivations, attitudes and behaviours; examples provided in Box 4.5.

**Persuasive Systems Design (PSD) Principles Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps**

- Self-Monitoring
- Tailoring
- Tunnelling
- Reduction
- Praise
- Personalisation
- Reminders
- Suggestions
- Liking
- Social Role
- Rewards
- Social Support
- Social Comparison
- Social Competition
- Recognition
- Social Learning
- Normative Influence
- Social Facilitation

*Box 4. 5: Persuasive Systems Design (PSD) Principles Commonly Used in the Design of mHealth Physical Activity Behaviour Change Intervention Apps [Source: Researcher's own construction, informed by various studies]*

*Table 4. 1: Persuasive Systems Design (PSD) Principles for mHealth Physical Activity Behaviour Change Intervention Apps [Source: Researcher's own construction, informed by Oinas-Kukkonen and Harjumaa (2009) and Matthews, et al. (2016)]*

| **Persuasive Systems Design (PSD) Principles for mHealth Physical Activity Behaviour Change Intervention Apps** | | | |
|---|---|---|---|
| | **PSD Principle** | **Description** | **Example** |
| **Primary Task Support** | Reduction | App reduces complex behaviour into simple tasks to help reduce the effort users expend to perform the target behaviour. | App automatically monitors daily steps using inbuilt motion sensor technology. |
| | Tunnelling | App guides users through the process of behaviour change by providing opportunities and actionable means that brings them closer to the behaviour. | App requests user to answer a series of questions, which inform future suggestions and means for action. |
| | Tailoring | App tailors information to the potential needs, interests, personality, usage context and other factors relevant to a user group. | App includes a virtual personal trainer who provides different information content for different user groups (e.g. beginners, intermediate, advanced). |
| | Personalisation | App offers users personalised content or services on an individualised level. | App provides users with individualised content and suggestions based on their personal information. |
| | Self-monitoring | App allows users the opportunity to track and record their behavioural performance, to support them in achieving their goals. | App provides manual logging and/or automatic tracking of physical activity, in the form of step count, distance travelled, active time, and other self-evaluation criteria. |
| | Simulation | App provides users with means to observe the links between cause and effect with regard to the target behaviour. | App offers users to see before and after pictures of people who have engaged in and improved their physical activity levels. |
| | Rehearsal | App permits users to rehearse and repeatedly practice the target behaviour. | App allows users to rehearse and repeat exercises for practice. |
| **Dialogue Support** | Praise | App provides praise to users, in the form of words, images, symbols or sounds, as a way to provide user feedback information on their target behavioural performance. | App provides users with messages praising their behavioural performance and goal accomplishments. |
| | Rewards | App provides users with virtual rewards to give them credit for performing the target behaviour and for achieving their goals. | App provides users with virtual trophies upon completion of a task or goal, or for achieving a new personal best record. |
| | Reminders | App reminds users of the target behaviour. | App reminders users to log their manual data, or reminds them to engage in the target behaviour. |
| | Suggestion | App offers fitting suggestions related to the target behaviour. | App recommends that an exercise activity be engaged with in a particular way. |
| | Similarity | App aims to imitate its users in some specific meaningful way. | App uses slang language that is familiar and popular with a specific age group (e.g. teenagers). |
| | Liking | App is visually attractive to users, and provides a look and feel that creates for positive user experiences. | App provides users with information and feedback in a visually appealing, pleasurably and fun, light-hearted way. App includes metaphorical representations. |
| | Social role | App adopts a social role. | App has a virtual personal trainer that the user can interact and compete with when exercising. |

| | | | |
|---|---|---|---|
| **System Credibility Support** | Trustworthiness | App provides users with information that is trustworthy, truthful, fair and unbiased. | App provides trustworthy information on WHO physical activity guideline recommendations. |
| | Expertise | App provides users with information showing knowledge, experience and competence. | App is updated regularly and information is kept up-to-date. |
| | Surface credibility | App provides a credible and competent look and feel. | App is visually appealing, clear and professional. |
| | Real world feel | App provides users with information of the persons/organisation behind its content and services. | App provides users with means to reporting issues and contacting the developers/ company behind the app. |
| | Authority | App refers to persons in authoritative roles. | App includes information provided by well-known, credible personal trainers. |
| | Third-party endorsements | App has third-party endorsements from respected and well-known sources. | App is endorsed by a personal training company or well-known personal trainer. |
| | Verifiability | App provides users with means to verify the accuracy of its content with credible outside sources. | App provides users with information that securely links to credible websites of external organisations. |
| **Social Support** | Social learning | App provides users with opportunities to observe others performing the target behaviour, and to see the outcomes/results of performing that target behaviour. | App allows users to follow and view the information of other app users that share common interests, through user profiles or message forums. |
| | Social comparison | App permits users with means to compare their behavioural performance with other app users. | App allows users to compare their physical activity performance and achievements with other app users. |
| | Normative influence | App provides users with means to engage with other app users who share the same/ similar goals as them, leveraging normative influence and peer pressure. | App provides users with positive images of others performing a specific physical activity to motivate behavioural performance. |
| | Social facilitation | App provides users with means for discerning that other app users are performing the target behaviour with them. | App allows users to observe other app users performing the behaviour with them, or allows them to exchange virtual gifts with other app users for reaching goals. |
| | Cooperation | App provides users with means of cooperating with other app users, with regard to the target behaviour. | App assigns users to groups with other app users, who then work together/cooperate to achieve goals/compete against other teams. |
| | Competition | App provides users with means of competing another other app users, with regard to the target behaviour. | App allows users to compete against a virtual avatar when performing a specific behaviour (e.g. running). App allows users to compete for achieving certain targets. |
| | Recognition | App provides users with public recognition when they perform the target behaviour. | App allows users to share their personal stories with other users, and recognises their performance and goal achievements. |

There is a challenge in that many intervention designers (particularly from the health behavioural sciences perspective) are "often not aware of the subtle messages the technology in itself can convey" (Geuens, et al., 2016, p.166). They often tend to view "mobile technology as a mere tool that has no effect or value and serves only as a vehicle for delivery of intervention content" (Geuens, et al., 2019a, p.353). This means that the translation and operationalisation

of theories, BCTs and PSD principles into app design features is often neglected from the health behavioural sciences perspective, but from the information systems perspective is considered crucial to the success and effectiveness of mHealth (physical activity) behaviour change intervention apps (Blandford, et al., 2018; Cotton and Patel, 2019). Overcoming this challenge requires active listening, communication and negotiation between collaborating persons from both perspectives (Carlile, 2002; 2004). Flexible descriptions and interpretations of BCTs and PSD principles often magnifies how difficult this bridging process can be (Geuens, et al., 2016; Fadhil and Wang, 2019). Some BCTs and PSD principles – such as those relating to "self-monitoring", "rewards", "reminders", "social support" and "social comparison" – also overlap, which further complicates terminological ambiguity and flexible interpretation between the two perspectives (Geuens, et al., 2016; Fadhil and Wang, 2019; Geuens, et al., 2019a).

These challenges are amplified in that there are innumerable ways in which theories, BCTs and PSD principles can be translated and operationalised as app (user interface) design features across different physical activity apps (Sporrel, et al., 2021); a challenge that Kaptein, et al. (2015, p.39) describe as having "differing levels of exhaustiveness, exclusively, emphasis, and granularity". The different translation and operationalisation of BCTs and PSD principles can be clarified by an example, using "rewards" as a shared BCT and PSD principle. In the *Starfish* physical activity app (Paul, et al., 2017, p.2), upon reaching a daily 10 000 step-count target goal for at least five days of a week, users receive a "reward" operationalised through the provision of an additional "sea creature", represented as a "crab" or an "octopus" in their app's on-screen "fish tank". The *CARROT Fit* physical activity app offers "rewards" to users through the provision of "credit points" (Larsson, 2015, p.20). The *UbiFit Garden* app (Consolvo, et al., 2008; Munson and Consolvo, 2012) generates a glanceable image display of a garden on the user's smartphone wallpaper interface, and offers "rewards" in the form of a virtual "flower" for each activity performed and a "butterfly" upon goal attainment. Other physical activity apps operationalise "rewards" offered through points and bonus points [*NEAT'O'GAMES* (Fujiki, et al., 2008) and *PLAY, MATE!* (Berkovsky, et al., 2010)], virtual markets and virtual currency [*Move2Play* (Bielik, et al., 2012)], and through ribbons and trophies [*GoalPost* and *GoalLine* (Munson and Consolvo, 2012)]. In Vaquero's (2016, p.38) *SportyPlanner* physical activity app, "rewards" are operationalised in the form of virtual "badges" which can be accumulated and converted into real-life "discount vouchers" for users to use when purchasing items from online sport stores. Other physical activity apps *Fitbit* (Munson and Consolvo, 2012), *StepStream* (Miller, 2014) and *MAPS* (Fanning, 2016) also

"reward" users with virtual "badges". This example of the different translations and operationalisations of "rewards" demonstrates the vast number of ways theories/mechanisms of action, BCTs and PSD principles can be applied as design features in physical activity apps.

Identifying and labelling, and hence reporting on, various BCTs and PSD principles is made more difficult in that particular app design features are not necessarily informed by specific BCTs or PSD principles (Sporrel, et al., 2021). "Rewards" (both a BCT and PSD principle), for instance, can be operationalised as a "virtual badge" (app user interface design feature); however, the presence of a "virtual badge" (app user interface design feature) in an mHealth physical activity app can be informed by more than one BCT, such as "rewards" and "feedback on behaviour" (Fanfarelli, Vie and McDaniel, 2015). In light of these challenges pertaining to the translation and operationalisation of theories/mechanisms of action, BCTs and PSD principles, app designers should provide "rationales for [their] design choices" (Geuens, et al., 2016, p.167). App designers should also clearly state their hypotheses as to how certain app design feature and user interface design choices are likely to motivate app users' behaviour changes (Geuens, et al., 2016; Sporrel, et al., 2021). The "reward design pattern" (Alahaivala, Odour and Oinas-Kukkonen, 2014) and "social influence design pattern" (Odour, Alahaivala and Oinas-Kukkonen, 2014) are examples of detailed guidelines for assisting app designers in the technical reporting of specific BCT and PSD principle translations and operationalisations as app design features.

The translation and operationalisation of theories/mechanisms of action, BCTs and PSD principles as app design features also relates to concerns and challenges regarding the importance of user interface design, mobile user experience design, usability, user acceptance/adoption, user engagement, and the perceived usefulness and quality of mHealth physical activity behaviour change intervention apps. These arguments are generally made from an information systems perspective and are often associated with the potential effectiveness of physical activity apps (Matthews, et al., 2016; Blandford, et al., 2018; Baretta, Perski and Steca, 2019; Liew, et al., 2019). To clarify some these terms from an information systems perspective, usability is a measure of how well an app user in a specific context can use an app to perform tasks and achieve defined goals effectively, efficiently and satisfactorily, and considers factors such as memorability, learnability, errors, efficacy and satisfaction (Alturki and Gay, 2017). Mobile user experience design refers to the subjective (positive and negative) experiences and emotions users have with a mobile app (Botha, 2011), which

considers elements including usability, usefulness, desirability, findability, accessibility, credibility and value (Morville, 2004).

Notably though, the critical literature review revealed that, from a health behavioural sciences perspective, some design related terms refer to the design of the intervention and its constituting components and BCTs, rather than the design of the app itself as the mode/platform of intervention delivery. Examples of such terms are "usability", "effectiveness", "design", "implementation", "evaluation", "piloting", "feasibility", "testing", "user experience", "adoption", "user acceptance", "user satisfaction", "user engagement", "usefulness", "user enjoyment", "attractiveness", "persuasiveness", and "motivation" (Yardley, et al., 2015a; 2015b; 2016; Blandford, et al., 2018; Morrison, et al., 2018; O'Cathain, et al., 2019; Rousseau, et al., 2019; Tharchen, Garud and Henn, 2020). These different interpretations, meanings and understandings of certain terminology describes a phenomenon referred to as interpretive flexibility (Star and Griesemer, 1989; Star, 2010). Essentially, from an information systems perspective, these terms are generally associated with the relationship between the app and the app users/consumers. Whereas, from a health behavioural sciences perspective, these terms are generally associated with the relationship between the intervention (and its constituting components) and the intervention consumers.

In keeping with the information systems perspective, app-specific studies that have argued for the importance of human computer interaction, usability, user acceptance/adoption, user engagement, perceived usefulness, and mobile user experience design include *iStepLog* (Kirwan, et al., 2012a), *Accupedo-Pro Pedometer* (Kirwan, et al., 2012b), *Zombies, Run!* and *Couch-to-5K* (Direito, et al., 2015), *Twazon* (Alturki and Gay, 2017), *VIDEA bewegt* (Fischer, et al., 2019), *SUPER-HEALTH* (Lai, et al., 2019), *PuzzleWalk* (Kim, et al., 2020; Lee, et al., 2020), and *Daily Yoga* (Yu and Huang, 2020). Creating for positive mobile user experiences and designing physical activity apps with "high-quality graphic design, visual appeal, and ease of use are more likely to attract potential customers [consumer app users]" (Bondaronek, et al., 2018, p.11). Studies on popular physical activity consumer apps on the Google Play and Apple App Stores are shown to exhibit positive correlations between the design quality of apps (usability, information quality, user engagement, number of BCTs, and users perceptions) and increased app effectiveness and measurable physical activity behaviour change (Bardus, et al., 2016; Schoeppe, et al., 2017). These study findings demonstrate the complex relationship between both the information systems and health behavioural sciences perspectives, and that

the two perspectives tend to influence and relate to one another. Some other studies, however, have found a few popular physical activity consumer apps on the Google Play and Apple App Stores as not including key BCTs and PSD principles that supposedly effectively motivate physical activity behaviour change (Vaquero, 2016).

From an information systems perspective, studies have revealed other mHealth physical activity app usability issues to include: an excess provision of information content on apps' screens and glanceable displays; a lack of help and documentation for navigating apps; confusing information displays; lack of personalised functionalities; and insufficient feedback on performance (Vaquero, 2016). Furthermore, user acceptance, user adoption, user engagement, and long-term sustained usage is often reported as a challenge in the design of effective physical activity consumer apps (Althoff, et al., 2016; Jee, 2017; Khamzina, et al., 2020; Laato, et al., 2020). In light of these usability related challenges, several frameworks, models and measurement scales from the information systems perspective have been proposed. These include: the *App Behaviour Change Scale (ABACUS)* (McKay, Slykerman and Dunn, 2019); the *Health Information Technology Usability Evaluation Model (Health-ITUEM)*; the *Mobile App Rating Scale (MARS)* (Hides, et al., 2014; Stoyanov, et al., 2015); the *User Version of Mobile App Rating Scale (uMARS)* (Stoyanov, et al., 2016); the *Extended Unified Theory of Acceptance and Use of Technology (UTAUT2)* (Venkatesh, Thong and Xu, 2012), and the UTAUT2's extended version to smartphone physical activity apps in particular (Dhiman, et al., 2020). Despite these contributions, there remain calls for future studies into the acceptance, adoption, usability, sustained engagement and long-term usage of mHealth physical activity behaviour change intervention apps (Aslam, et al., 2020; Chatterjee, et al., 2021).

To further help overcome challenges of acceptance, adoption and sustained engagement, physical activity apps are increasingly harnessing the persuasive power of gamification (Wong and Kwok, 2016; LeBlanc and Chaput, 2017; Tu, Hsieh and Feng, 2018; Cotton and Patel, 2019; Othman, Ugap and Rahman, 2019; Lee, et al., 2020). In fact, gamification has become "immensely popular in commercial PA [physical activity] and health mobile apps for the past decade" (Lee, et al., 2020, p.2993). One of the most popular, well-known and successful gamified physical activity apps worldwide is *Pokémon GO* (LeBlanc and Chaput, 2017). Studies have shown *Pokémon GO* to significantly increase individuals' physical activity (Althoff, et al., 2016; Howe, et al., 2016; Khamzina, et al., 2020; Laato, et al., 2020), and improve their motivation, behavioural intention, positive affect, socialisation and general

wellbeing (Arjoranta, Kari and Salo, 2020; Laato, et al., 2020). Long-term retained engagement and sustainable usage with *Pokémon GO* has, however, been noted as a challenge requiring future research – a frequently documented challenge with most physical activity consumer apps (LeBlanc and Chaput, 2017; Khamzina, et al., 2020).

Gamification is the use of game design elements such as badges, points, levels, rewards, prizes, avatars, leaderboards and competitions in the design of mHealth consumer apps, with the intention of increasing users' engagement and enjoyment with using the apps, resulting in increased motivation and real world physical activity behaviour change (Edwards, et al., 2016; Cotton and Patel, 2019; Othman, Ugap and Rahman, 2019). Gamification works by tapping into the playful, social, emotional and goal-driven aspects of human nature, and includes strategies such as goal setting, providing feedback on performance, reinforcement, social support, social comparison and social competition (Edwards, et al., 2016). Gamification techniques are used in tandem with and, at times, overlap with BCTs and PSD principles (Edwards, et al., 2016; Lee, et al., 2020). For example, as a persuasive gamified app, *Pokémon GO* uses strategies such as reaching new higher levels, catching new Pokémon, evolving new Pokémon, hatching eggs, fighting (collaboratively with others, or individually), comparing oneself to and competing against other app users, and social networking and bond strengthening (Arjoranta, Kari and Salo, 2020). Moreover, some gamified physical activity apps are designed using theory/mechanisms of action and determinants/correlates (for example, *CityU Walk* (Wong and Kwok, 2016), *WeChat Sports* (Tu, Hsieh and Feng, 2018), *Play4Fit* (Othman, Ugap and Rahman, 2019), and *PuzzleWalk* (Kim, et al., 2020; Lee, et al., 2020)), while studies reveal some other apps do not have theoretical/determinant bases (Cotton and Patel, 2019). For many apps that did not report the use of theory, the theoretical underpinnings/mechanisms of action tend to be unstated, but when reviewed, do in fact implicitly link to key theories/mechanisms of action and determinants/correlates; relating back to challenges associated with poor reporting (Bohlen, et al., 2019; Cotton and Patel, 2019; Fiedler, et al., 2020).

The usability of mHealth physical activity behaviour change intervention apps, from an information systems perspective, is crucial for ensuring that users are able to properly use and engage with apps in a meaningful and satisfying way. Failures and issues with the usability, acceptance, adoption, engagement, user experience, sustained usage and perceived usefulness of mHealth physical activity behaviour change intervention apps has a negative impact on the

potential effectiveness of the intervention itself and its constituting components (which are built and operationalised into the app) (Bondaronek, et al., 2018; Sporrel, et al., 2021). Overall, the design challenges discussed thus far (BCTs, PSD principles, usability, mobile user experience design, user interface design, acceptance/adoption, and sustained usage) are often interconnected with challenges regarding theory, multi- and interdisciplinary processes and effectiveness.

Effectiveness is imperative for mHealth intervention apps to successfully influence and persuade individuals to positively change and modify their physical activity behaviour. As the case with terms such as "usability", the term "effectiveness" is interpreted flexibly from both perspectives. From an information systems perspective, "effectiveness" generally refers to whether the app and its built-in tasks do what the user wants them to do, in order to achieve one or more specific goals (Blandford, et al., 2018; Sporrel, et al., 2021). However, this interpretation and use of the term is markedly distinct to the health behavioural sciences perspective. From a health behavioural sciences, the term "effectiveness" generally refers to whether the intervention and its constituting components, BCTs and content is able to positively change individuals' realised/actual physical activity behaviour (Blandford, et al., 2018). In essence, effectiveness from an information systems perspective is concerned with whether the app works adequately (the mode of intervention delivery as a software product), whereas effectiveness from a health behavioural sciences perspective is concerned with the intervention works adequately (which is built into and delivered through the app/software product).

Effectiveness, when compared between both perspectives, usually carries a weightier importance from the health behavioural sciences perspective. This, generally speaking, stems from centuries of the health, medical and behavioural science fields giving priority emphasis to trials and variables that can be clinically and numerically measured, tracked, analysed and generalised (Blandford, et al., 2018). Given this historical influence, the effectiveness of mHealth physical activity behaviour change intervention apps is often measured in terms of realised/actual behaviour change and anthropometrics (such as body weight, body mass index (BMI), body circumferences, and skinfold thickness) (Recio-Rodriguez, et al., 2016; 2018; Dugas, Gao and Agarwal, 2020). The "gold standard" of evidence for effectiveness are large, long-term randomised controlled trials (RCTs), which are valued for their rigour and validity (Dick, O'Connor and Heavin, 2017, p.2). Although, as mobile and digital technology has

become increasingly popular as a mode/platform of intervention delivery, measuring the effectiveness of mHealth physical activity behaviour change intervention apps as broadened to measure the strength and correlations of specific intervention components and BCTs, as well as the mobile platform (McCallum, 2019). Examples of such methods include the *Multiphase Optimisation Strategy (MOST) method* (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018), the *Sequential Multiple Assignment Randomised Trial (SMART) method* (Collins, Murphy and Stretcher, 2007), and the *Trials of Intervention Principles (TIPS) method* (Mohr, et al., 2015). A framework for *Operationalising Single Case Designs for physical activity apps Distributed via App Stores (the OSDAS Framework)* has also been proposed (McCallum, 2019). Notably though, depending on the scale and duration of studies, it is necessary to distinguish between whether a physical activity intervention app is effective (performs well in uncontrolled real world conditions, where external factors cannot be manipulated or controlled for) or efficacious (performs well under ideal and controlled conditions with well-defined groups of study participants) (Lee, et al., 2019). Nevertheless, studies on the feasibility, efficaciousness and effectiveness of mHealth physical activity behaviour change intervention apps have gradually increased in recent years; although there are continuous and current calls for more large-scale effectiveness studies to gather additional evidence for determining the effectiveness of such apps (Lee, et al., 2019; Dugas, Gao and Agarwal, 2020; Chatterjee, et al., 2021).

The effectiveness of mHealth physical activity behaviour change intervention apps, investigated through systematic reviews and meta-analyses, have largely revealed mixed findings (Jee, 2017; Palmer, et al., 2018; Lee, et al., 2019; Dugas, Gao and Agarwal, 2020). Although some study findings have been positive (Mateo, et al., 2015; Coughlin, et al., 2016; Romeo, et al., 2019; Mitchell, et al., 2020), yet the statistical changes are often modest (Coughlin, et al., 2016; Covolo, et al., 2017; Eckerstorfer, et al., 2018; Romeo, et al., 2019; Laranjo, et al., 2020; Mitchell, et al., 2020). Mixed findings have been explained in terms of the quality of methodologies used to evaluate the effectiveness of mHealth physical activity intervention apps, emphasising the need for larger sample sizes, longer intervention trial periods, longer follow-up periods and overall higher quality, rigorous study designs (Coughlin, et al., 2016; Covolo, et al., 2017; Yerrakalva, et al., 2019; Laranjo, et al., 2020). The need for improved reporting and better dissemination of effectiveness study findings are also reported (Zhao, Freeman and Li, 2016; Eckerstorfer, et al., 2018; McCallum, 2019; Fiedler, et al., 2020). Furthermore, user adherence and sustainable engagement are often reported to drop after about

three months (Jee, 2017; Romeo, et al., 2019). Challenges with mixed findings and long-term user adherence have led to calls for more investigations into determining which specific BCTs, PSD principles and app design features are positively correlated with increased app engagement usage, intervention adherence and intervention effectiveness (Zhao, Freeman and Li, 2016; Covolo, et al., 2017; Tong, et al., 2018; Villinger, et al., 2019). There has also been an increase in calls for studies to investigate the effectiveness of mHealth physical activity app content for specific cultural and vulnerable populations (Coughlin, et al., 2016; Sullivan and Lachman, 2017), such as the *OL@-OR@* app for the indigenous Māori and Pasifika communities in New Zealand (Morenga, et al., 2018; Verbiest, et al., 2018; Ni Mhurchu, et al, 2019).

Studies investigating the effectiveness of specific commercial and research physical activity apps have also been mixed, although often positive, and have generally been measured in terms of usability, app design, anthropometrics and physical activity participation levels. App-specific studies that have shown positive increases in physical activity levels include: *MyDayPlan* (Degroote, et al., 2020); *Carrot Rewards* (Mitchell, et al., 2020); *Pokémon GO* (Khamzina, et al., 2020); *ParticipACTION* (Truelove, et al., 2020); *Fit.Healthy.Me* (Tong, et al., 2019); *Puzzle Walk* (Lee, et al., 2018b); *Active2Gether* (Middelweerd, et al., 2018); *EVIDENT II* and *EVIDENT 3* (Recio-Rodriguez, et al., 2016; 2018); *TODAY* (Direito, et al., 2018); *bActive* (Harries, et al., 2016); *Runkeeper*, *Nike+ iPod*, *Endomondo* and *Strava* (Dallinga, et al., 2015); *Zombies, Run!* and *Couch-to-5K* (Direito, et al., 2015); *MyBehaviour* (Rabbi, et al., 2015); *Accupedo-Pro Pedometer* (Glynn, et al., 2014); *Lose It!* (Allen, et al., 2013); and *iStepLog* (Kirwan, et al., 2012). These studies were conducted over different timeframes, generally spanning six weeks, three months, six months and one year.

Additional studies have been conducted on the top (free and paid) physical activity apps available for download on public commercial app markets (namely the Google Play and Apple App Stores) (Conroy, Yang and Maher, 2014; Knight, et al., 2015; Modave, et al., 2015; Bardus, et al., 2016; Vaquero, 2016; Schoeppe, et al., 2017; Bondaronek, et al., 2018; McKay, et al., 2019). These studies tend to examine the effectiveness, usability, content, quality, theory, BCTs, PSD principles, design features and users' experiences of the top publicly available physical activity consumer apps. Tools to conduct these studies often include the *System Usability Scale (SUS)*, the *App Behaviour Change Scale (ABACUS)*, the 5-point *Mobile App Rating Scale (MARS)*, the *Behaviour Change Technique (BCT)* taxonomies, the WHO's *Global*

*Physical Activity Guideline Recommendations*, and various types of trials (such as RCTs). The MARS scale, for instance, has been used to evaluate several physical activity apps, including *MyFitnessPal*, *NexTrack*, *MSN Health & Fitness*, *My Diet Coach Pro* (Bardus, et al., 2016), *Inspirun* (Vos, et al., 2016), as well as *Fitbit, Sworkit, Zombies Run!, Walkr, NFL Play, Pokémon GO, Kurbo, Runbit, Ninja Fitness, Dungeon Runner, iBitz, and Kid's Fitness* (Schoeppe, et al., 2017). Studies that employ tools from both the health behavioural sciences and information systems perspectives are generally more rigorous and holistic, largely because they aim to investigate and assess the effectiveness and potential of mHealth behaviour change itnervention apps in terms of both the intervention and the digital platform (app).

Figure 4.5 provides a summary of the mHealth (physical activity) behaviour change intervention app design related challenges discussed to this point in the discussion, specifically concerning their (1) design, (2) underpinning theory, and (3) effectiveness.

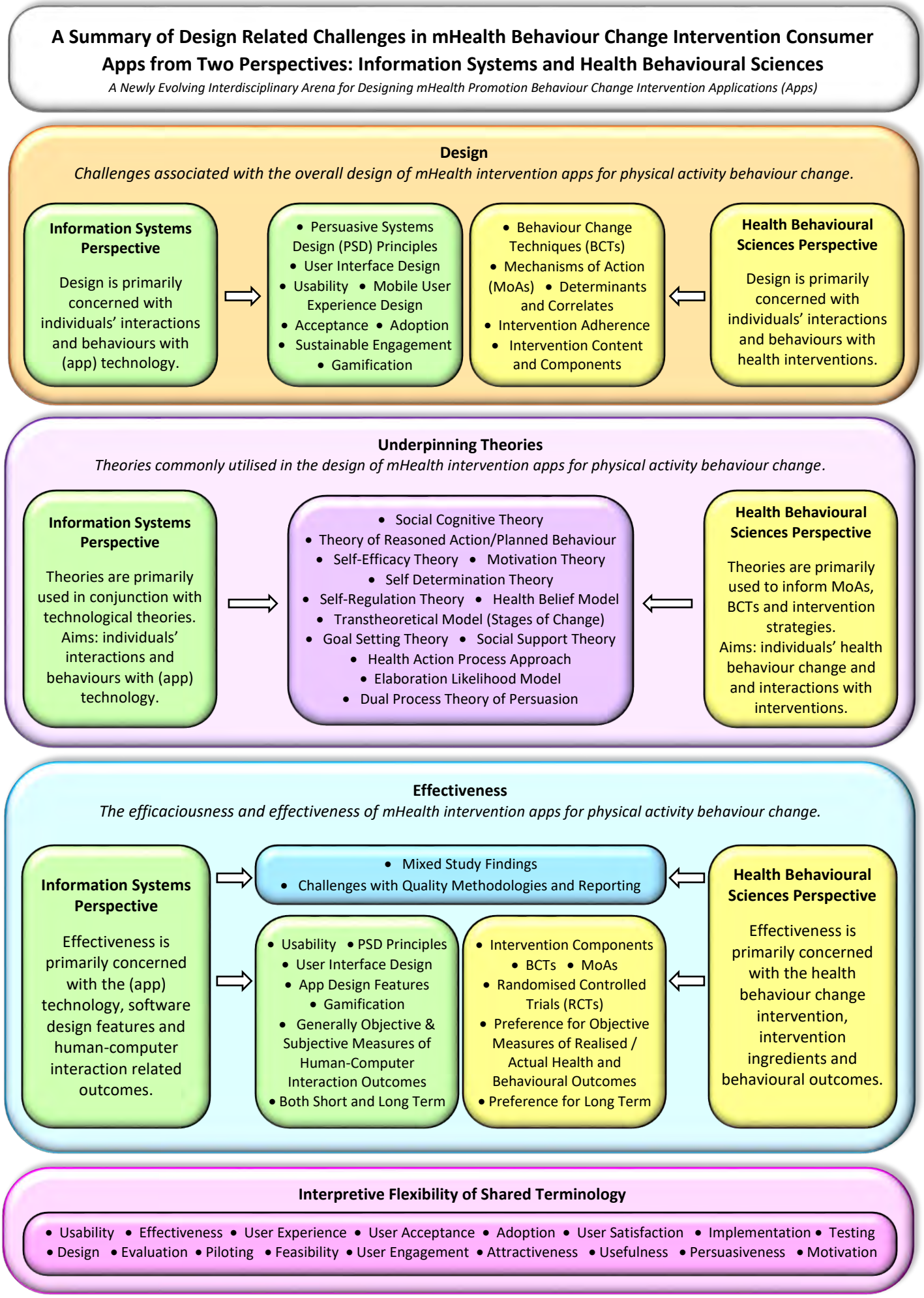



*Figure 4. 5: A Summary of Design Related Challenges in mHealth Behaviour Change Intervention Consumer Apps from Two Perspectives: Information Systems and Health Behavioural Sciences*

*[Source: Researcher's own construction]*

*Interdisciplinary collaborations that bring together not only technologists and health researchers but also human computer interaction experts are needed. These collaborations will benefit the field of digital health and support the design of interventions capable of not only temporar[il]y changing behaviours but also saving lives.*

*– Sellak and Grobler (2020, p.45) –*

### 4.4.3 Approaches to Designing, Developing and Evaluating mHealth Behaviour Change Intervention Consumer Apps: Challenges and Opportunities

Along with the design challenges of mHealth (physical activity) behaviour change intervention apps (summarised in Figure 4.5), calls for collaborations between specialists from the health behavioural sciences and information systems perspectives have increased, to improve the apps' overall design and effectiveness (Demiris, 2012; Kostkova, 2015; Knittle, et al., 2016; Peiris, Miranda and Mohr, 2018; Blandford, 2019b; Bul, et al., 2020). More specifically, there have been growing calls for multi- and interdisciplinary frameworks, approaches and processes that can guide the "holistic" collaborative design, development and evaluation of mHealth behaviour change intervention apps (Van Gemert-Pijnen, et al., 2011, p.1; Perski, et al., 2017; Blandford, et al., 2018; Blandford, 2019b; Wang, et al., 2019, p.1; Bendtsen, et al., 2020; Damen, et al., 2020; Hermsen, et al., 2020; Sucala, et al, 2020; 2021).

In a study focusing on mHealth behaviour change intervention apps for physical activity specifically, Sullivan and Lachman (2017, p.1) highlight the ongoing need for "ways in which app developers and behaviour change experts can collaborate to develop successful [physical activity] apps". Notably though, the disciplines and specialisations relevant and necessary to the design, development and evaluation of mHealth (physical activity) behaviour change intervention apps is broader than Sullivan and Lachman's (2017, p.1) simple reference to "app developers" and "behaviour change experts". These two sides mirror the high-level, simplified and abstract differentiation between the information systems and health behavioural sciences perspectives, respectively (presented in Subsection 4.4.1). A more honed and precise view considers several areas of expertise, which stem from both of these two perspectives (Blandford, et al., 2018). These areas of expertise include: human-computer interaction; (mobile) user experience design; human factors engineering; software engineering; user-centred design; persuasive technology; persuasive systems design; computer sciences; health behaviour change support systems; gamification; health sciences; behaviour and behaviour change sciences; public health; health promotion; health psychology; psychology (general,

clinical, counselling, research and educational); healthcare professionals; experts in various lifestyle-specific domains of health behaviour (such as physical activity, exercise/sport science, dietetics and nutrition), and more. While acknowledging all of these areas of specialisation and expertise are important to understanding the production of mHealth (physical activity) behaviour change intervention apps, the process for designing, developing and evaluating these apps are generally approached from the two broad health behavioural sciences and information systems perspectives.

#### 4.4.3.1 Approaches to mHealth Behaviour Change Intervention Consumer Apps: Integrating Two Perspectives

To reiterate a point conveyed in Subsection 4.4.1, the health behavioural sciences perspective generally offers approaches/processes that align with *intervention development* (guiding the design, development and evaluation of health behaviour change interventions), whereas the information systems perspective generally offers approaches/processes that align with the *systems (or software) development lifecycle* (guiding the design, development and evaluation of technology/systems). Blandford, et al. (2018) and Blandford (2019a; 2019b) explicitly highlight and discuss the similarities and differences between the typical approaches/processes for health (which they term for encompassing health intervention sciences and health psychology) and information systems (which they term under human-computer interaction (HCI)). Many of these similarities and differences are echoed in an earlier publication by Pagliari (2007), which distinguishes between design, development and evaluation approaches, processes and methods between user-centred design (under the umbrella of software and usability engineering) and health (under the umbrella of health services research).

On the one hand, the health approach to digital health interventions is generally informed by the Medical Research Council's (MRC's) process outlined in the document for *Developing and Evaluating Complex Interventions: New Guidance* (Craig, et al., 2008; 2013). This approach is focused on providing a sequential model for designing, developing and evaluating interventions that culminate in a RCT to determine clinical effectiveness, long-term engagement and health outcome measures (Blandford, et al., 2018; Blandford, 2019a). A more recently proposed health approach is the *Person-Based Approach to Digital Health Behaviour Change Intervention Development* (Yardley, et al., 2015a, p.1), which provides a process for guiding the development of digital health behaviour change interventions by focusing on "understanding and accommodating the perspectives of the people who will use the

intervention". Notably, Yardley, et al.'s (2015a) approach can be argued as a multi- or interdisciplinary approach, although it is predominately perceived from the health behavioural sciences perspective. On the other hand, the information systems (or HCI) approach is generally informed by systems and software development lifecycle processes such as the International Organisation for Standardisation's (ISO's) standards and guidelines for *Ergonomics of Human-System Interaction (ISO 9241)* (ISO, 2010; Blandford, et al., 2018). Other common systems (software) development lifecycle approaches and models include *User-Centred System Design (UCSD)*, *Rapid Application Development (RAD)* and *Agile Development* processes, as well as more traditional approaches, such as *Waterfall*, *Spiral* and *Unified Process Model (UPM)* processes (Seffah, Gulliksen and Desmarais, 2005; Pagliari, 2007; Mishra and Dubey, 2013). In contrast to the health approaches, which offer a more systematic and rigid process, the more contemporary (non-traditional) information systems (or HCI) approaches provide a more flexible and iterative process for designing, development evaluating interventions by focusing on user needs, design rationale and process measures (Blandford, et al., 2018; Blandford, 2019a).

Figure 4.6 provides an overview of the two approaches generally used to guide the design, development and evaluation of digital health (mHealth) behaviour change interventions from the health behavioural sciences perspective, including namely the MRC's *Complex Interventions Development Approach* (the top diagram) and the *Person-Based Approach to Digital Health Behaviour Change Intervention Development* (the bottom diagram). Figure 4.7 provides an overview of the two approaches generally used to guide the design, development and evaluation of digital health (mHealth) behaviour change interventions from the information systems perspective, including namely a synthesised *Systems (Software) and User-Centred Systems Design (UCSD) Lifecycle Approach* (the top diagram) and the ISO's *Human-Computer Interaction (HCI) Development Lifecycle Approach* (the bottom diagram). Noticeably, in both Figure 4.6 and Figures 4.7, the diagrammatic approaches and processes from both perspectives are superficially similar in that they are both iterative and both incorporate phases for designing, implementing and evaluating digital (mHealth) behaviour change interventions. However, upon careful inspection, there is a notable difference in the real world application and practice of these approaches: health approaches/processes are iterative in theory, yet are usually a "one-off event" in real world practice, whereas information systems approaches/processes are iterative in theory and real world practice (Blandford, et al., 2018, p.2).

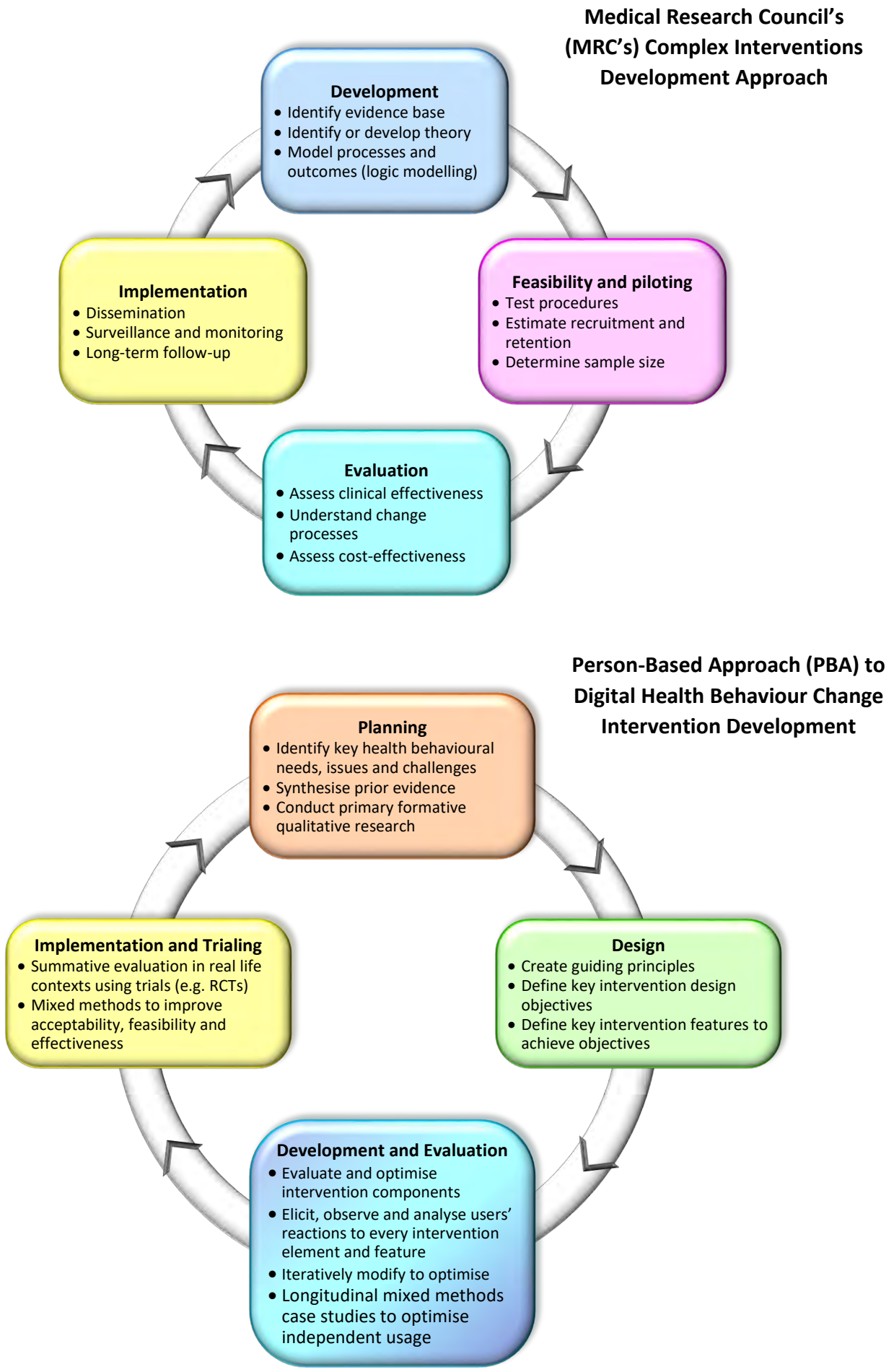



*Figure 4. 6: Typical Health Approaches and Processes to Digital Health (mHealth) Behaviour Change Intervention Development [Source: Researcher's own construction, informed by Craig, et al. (2008; 2013), Yardley, et al. (2015a), Blandford, et al. (2018) and Blandford (2019a)]*

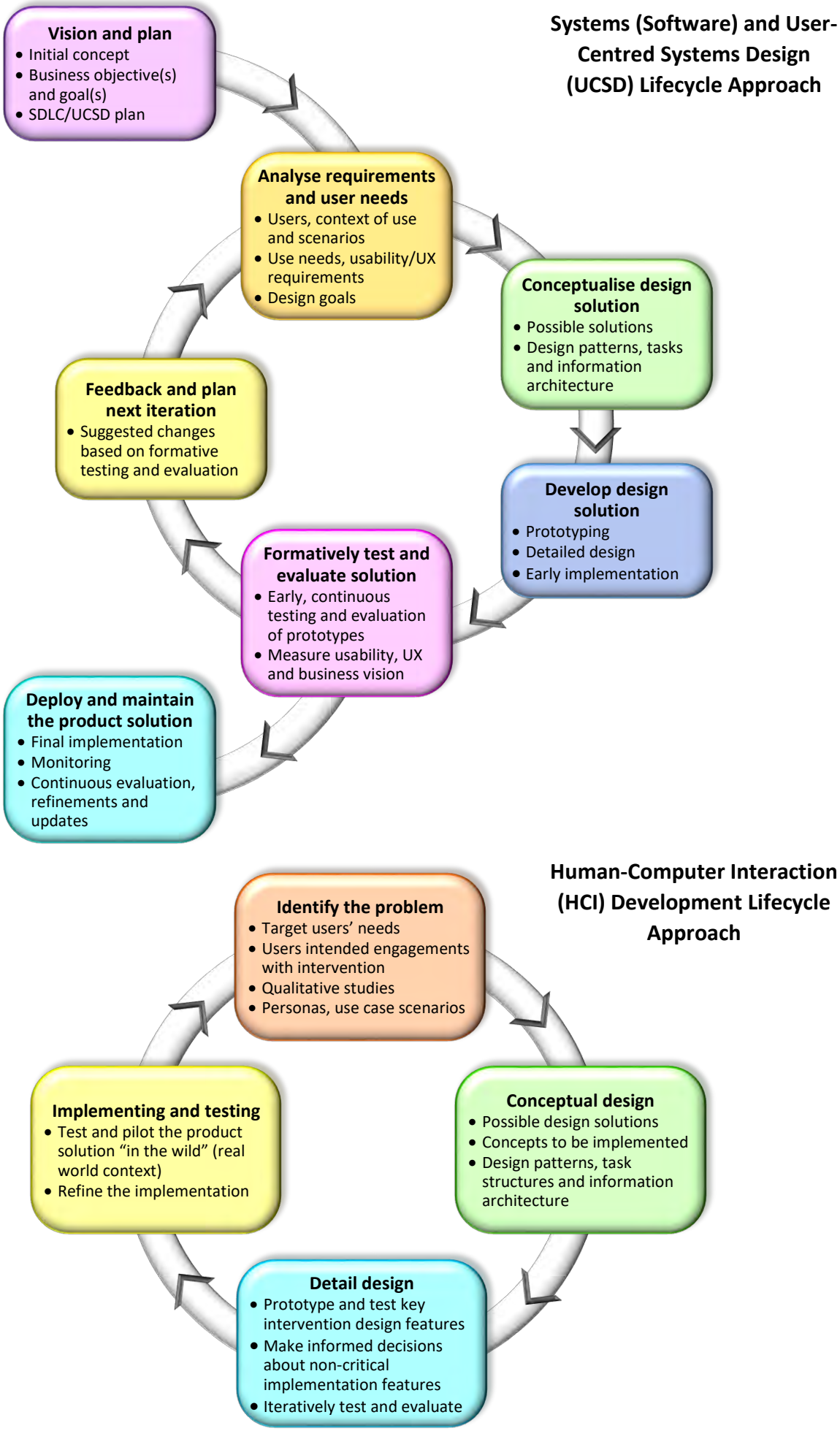



*Figure 4. 7: Typical Information Systems Approaches and Processes to Digital Health (mHealth) Behaviour Change Intervention Development [Source: Researcher's own construction, informed by Seffah, Gulliksen and Desmarais (2005), Blandford, et al. (2018) and Blandford (2019a)]*

In terms of the initial *requirements gathering* and *design* stages, the health approach assumes health psychologists, health behavioural intervention scientists and clinicians to be primary "experts", since professionals generally hold knowledge in health behaviour change theories, mechanisms of action and BCTs (that is, the active ingredients constituting digital (m)Health behaviour change interventions) (Blandford, et al., 2018, p.4). In contrast, the information systems approach assumes end users to be primary "experts", since end users are often placed at the centre of the UCSD process and are generally assumed to hold knowledge in what their needs, wants and preferences are (that is, in terms of solution objectives and design solution preferences) (Blandford, et al., 2018, p.4). This distinction is perceptible in Figures 4.6 and 4.7. Blandford, et al. (2018, p.7) emphasises that neither perspective is better than the other and that "both have an important contribution to make", subsequently explaining that digital (m)Health behaviour change intervention design, development and evaluation should draw on three kinds of knowledge and expertise, namely from (1) health professionals, (2) information systems professionals, and (3) end users. Hence, in recent years, approaches that employ co-design/co-creation and participatory design processes have been increasing in popularity in mHealth app design and development (Morenga, et al., 2018; Thabrew, et al., 2018; Verbiest, et al., 2018; Ni Mhurchu, et al, 2019).

*Design*, as a term and concept, is also viewed differently from the two health behavioural sciences and information systems perspectives (refer to Figures 4.6 and 4.7). The health approach generally refers to design in terms of the intervention, and the theories, mechanisms of action and BCTs making up the active ingredients of the intervention components (Blandford, 2019b). The information systems approach generally refers to design in terms of the software product (that is, the mHealth behaviour change intervention app software product), and views design in relation to the iterative low-to-high fidelity software/app prototyping process (Blandford, 2019b). Both perspectives are relevant to the design of effective mHealth behaviour change intervention apps, and both perspectives need to be considered and incorporated in the approach and process for producing successful and persuasive apps, such as those for physical activity promotion.

In addition, *implementation* as a term and concept is also viewed distinctly between health professionals and information systems professionals. The health approach generally refers to implementation as the final step of the process, when an intervention has already been fully tested and piloted, and is now being rolled out at scale (as illustrated in Figure 4.6) (Pagliari,

2007; Blandford, et al., 2018). In contrast, the information systems approach can refer to implementation in terms of large-scale roll out, but more so refers to software/app development and prototyping (Pagliari, 2007; Blandford, et al., 2018). This is when the intervention app is being iteratively coded, tested and refined with end users (such as beta testing with a sample of the consumer app market), and the concept of implementation is often interlaced with the concept of design (as illustrated in Figure 4.7) (Blandford, et al., 2018). In light of these different interpretations and meanings of implementation, both sides tend to invest time and resources into the different respective stages (Pagliari, 2007; Blandford, et al., 2018). Yet, both sides can learn from one another and both stages are important. The health perspective invests time and resources into ensuring that the digital intervention is effective at full scale, while the information systems perspective invests time and resources into ensuring that digital intervention is usable and useful, and that it demonstrates user acceptance/adoption, user satisfaction, usability and creates for positive user experiences (Blandford, et al., 2018). Generally speaking, both perspectives demand significant time and resources to effectively implement mHealth behaviour change intervention consumer app product solutions; time and resources that are seldom realistic or achievable in real world research and industry practice (Yardley, et al., 2015a; Bendtsen, et al., 2020).

*Evaluation* is another term and concept that is interpreted and understood differently from the two health behavioural sciences and information systems perspectives (refer to Figures 4.6 and 4.7). The health approach generally refers to evaluation that is summative in nature, whereas the information systems approach generally refers to evaluation that is formative in nature (Pagliari, 2007; Craig, et al., 2008; 2013; Blandford, 2019a). From the health perspective, summative evaluation methods are typically RCTs, or more recently, adaptive trial methods such as MOST, SMART and TIPS, although these contemporary methods are often perceived as less rigorous and inadequate in comparison to traditional "gold standard" RCTs (Dick, O'Connor and Heavin, 2017, p.2). Summative evaluation methods employed in the health approach usually involve extensive planning and large sample size recruitment, and tend to focus on the mHealth intervention app's long-term engagement and clinical and behavioural outcomes, effects and impacts (Blandford, 2019a; Milne-Ives, et al., 2020). From the information systems perspective, formative evaluation methods can vary, including prototype testing, expert reviews, user think-aloud protocols, task walk-throughs, group-based feedback and in-the-wild studies, and tend to focus on the mHealth intervention app's user acceptance/adoption, user satisfaction, user enjoyment, user engagement, motivation for use,

usefulness, persuasiveness, usability and user experience (Kasali, et al., 2017; Blandford, et al., 2018; Sucala, et al., 2020).

Another distinction is that formative evaluation methods are often qualitative in nature, and therefore tend to produce subjective findings, although some methods use quantitative methods, which produce objective measure findings – both of which are valued in information systems (Blandford, 2019a). In comparison, summative evaluation methods are typically quantitative in nature and therefore tend to produce objective findings, which, from a health behavioural intervention sciences perspective, are more valued and held to a higher esteem than qualitative methods and subjective measures (Blandford, 2019a). Nevertheless, in multi- and interdisciplinary team contexts, such as the mHealth behaviour change intervention app arena, formative evaluation has "huge benefits" and "these process measures matter", and while summative evaluation may have disadvantages (particularly in terms of the quickly evolving digital/technological environment), clinical effectiveness and "outcome measures matter" (Blandford, et al., 2018, p.8). In other words, both perspectives of evaluation matter.

As discussed in Subsection 4.4.2 and summarised in Figure 4.5, there are several terms and concepts that are interpreted flexibly depending on whether they are viewed from the heath behavioural sciences perspective or the information systems perspective. Some of the key terms and concepts relevant to the mHealth behaviour change intervention app process have been discussed above, namely *design*, *implementation* and *evaluation*. There are other related terms such as *piloting*, *testing* and *feasibility*, identified in Subsection 4.4.2 and summarised in Figure 4.5, which are also interpreted differently and hold different meanings when referred to in health or information systems approaches (Craig, et al., 2008; 2013; Blandford, et al., 2018; Blandford, 2019a; 2019b). In another study on the challenges of working across and betwixt the health and information systems perspectives, Pagliari (2007) also discusses issues arising with "non-shared concepts and language", and the dissimilar interests and motives, and "incompatible values" that derive from the two different cultures, epistemologies and paradigmatic worldview perspectives with two discernibly different historical roots (Blandford, et al., 2018, p.3). Pagliari (2007) and Blandford (2019a, p.75) note a concern in that the two sides lack awareness and exhibit "ignorance" with regards to each other's theoretical stances and modus operandi, which filter into different representations, interpretations, meanings and applied understandings of terms and concepts.

Successful collaboration requires mutual awareness, respect and trust for each other's perspectives, assumptions, aims, interests, motives, theories, approaches, processes and methods, as well as a willingness to step beyond one's own traditional and familiar community boundaries in order to practice in the multi- and interdisciplinary mHealth behaviour change intervention app arena (Pagliari, 2007; Blandford, et al., 2018). Failure to acknowledge and understanding each other's different perspectives, and linguistic interpretations and meanings can lead to confusion, miscommunication and mistrust, which can lead to the hindrance or failure of mHealth behaviour change intervention app projects (Pagliari, 2007; Blandford, et al., 2018). The challenges discussed above also represent opportunities for growth and "bridging the divide" between the two broad health behavioural sciences and information systems perspectives (Blandford, et al., 2018, p.11). Proactively engaging in the creation of shared understandings, methodological pluralism and "holistic" approaches are imperative to the multi-, inter- and ultimately transdisciplinary field of mHealth behaviour change intervention apps, such as those targeting the promotion of physical activity behaviour change (Pagliari, 2007; Van Gemert-Pijnen, et al., 2011, p.1; Wang, et al., 2019, p.1).

Despite the challenges stemming from the two different perspectives, and while overcoming the "sheer magnitude" of such challenges can be intimidating, there are some similarities and commonalities between the approaches/processes of health behavioural sciences and information systems (Blandford, 2019a, p.75). Both incorporate key process stage/step themes for planning, designing, developing, implementing and testing/evaluating (Blandford, 2019a). More importantly, both share the same ultimate aim, loosely stated, for developing, testing and producing "high quality" digital interventions for improving individuals' health and wellbeing (Pagliari, 2007, p.1; Blandford, et al., 2018; 2019a). Blandford (2019a, p.75) concludes that in order to "make a real difference, we need to bring [the two] complementary perspectives together" and that "working within and learning from the expertise and resources available to different disciplines" is imperative for progress and advancement in the emerging and evolving multi- and interdisciplinary mHealth behaviour change intervention app arena.

To address the challenges and leverage the opportunities presented by the two perspectives (and their various related areas of specialisation and expertise), Blandford (2019b, p.8) proposes an "integrated" development lifecycle which harnesses the strengths of "both worlds" – approaches and processes from both the health behavioural sciences and information systems perspectives. Blandford's (2019b) holistic approach comprises five main stages: (1) identify

the problem and planning; (2) conceptual design; (3) iterative design and evaluation; (4) implementation and testing; and (5) deployment and diffusion. While this integrated approach presents an informative contribution, it is relatively broad in its orientation towards "digital health technologies" in general, which encompasses a multitude of platforms such as those presented in Figure 4.3. This high-level abstract and generalised approach fails to incorporate some considerations, elements and activities that are pertinent to the design, development and evaluation of mHealth behaviour change intervention apps in particular and further lacks attention to the design challenges detailed in Subsection 4.4.2.

#### 4.4.3.2 Approaches to mHealth Behaviour Change Intervention Consumer Apps: A Critical Review

Along with Blandford's (2019b) integrated approach, and the increasing calls for theoretically- and evidence-based "holistic" multi- and interdisciplinary approaches that consider both the challenges and opportunities relating to design and approaches discussed in Subsections 4.4.2 and 4.4.3, respectively, several frameworks, approaches and processes have been proposed and published in the last decade. A critical review of nine holistic multi- and interdisciplinary approaches is provided in Appendix F. The nine approaches, which all propose combining and amalgamating the health behavioural sciences and information systems perspectives, are listed and referenced in Table 4.2 (listed in order of critical review, not chronologically). Notably, this critical review is not exhaustive. The primary purpose of conducting the critical review was to identify strengths and limitations of the current knowledge base on holistic multi- and interdisciplinary approaches, and more importantly, to identify knowledge gaps that can be improved upon in terms of addressing the thesis problem. The problem being that there exists a paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps, specifically for physical activity.

To address this thesis problem and in order to develop and propose the researcher's novel approach (which is to be presented in the following Chapter 5), a more detailed and thorough thematic and comparative critical theoretical review and analysis is performed in Chapter 6. This latter critical theoretical review analyses twenty existing holistic multi- and interdisciplinary approaches identified in the current knowledge base, and is informed by the proposed novel approach, thus making it more insightful, informative and relevant to the thesis content.

The critical review provided in Appendix F, and briefly discussed in this subsection, is therefore *preliminary* in nature. This preliminary critical review was performed when undergoing the exploratory research journey, yet played an important role in informing and leading to the thesis problem and proposed solution approach. Given its preliminary nature, it is excluded from the thesis main body discussion, and considering that all nine approaches are included in the later critical theoretical analysis, a discussion of them in this chapter would be redundant. In addition to being redundant, this preliminary critical review is slightly outdated (performed in early 2018), especially considering that two of the reviewed approaches have been subsequently updated and refined, namely, Geuens, et al. (2016) (updated to Geuens, et al., 2019a) and Wang, et al. (2017) (updated to Wang, et al., 2019). These updated and refined holistic multi- and interdisciplinary approach versions are reviewed and analysed in the latter thematic and comparative critical theoretical review and analysis (in Chapter 6).

To outline the digital mHealth (promotion) (physical activity) behaviour change intervention app development space, and build on the thesis problem argument, some of the strengths, limitations and knowledge gaps are presented in this main thesis body discussion. Some of the findings from the critical review performed in Appendix D are also used to inform the discussion on the strengths and limitations of current holistic multi- and interdisciplinary approaches, and to identify knowledge gaps in addressing the thesis problem.

*Table 4. 2: Holistic Multi- and Interdisciplinary Approaches: A Preliminary Critical Review [Source: Researcher's own construction]*

| **Holistic Multi- and Interdisciplinary Approaches: A Preliminary Critical Review** | | |
|---|---|---|
| **No.** | **Name of Approach** | **Reference** |
| 1 | The CeHRes Roadmap | Van Gemert-Pijnen, et al. (2011) |
| 2 | The Digital Intervention Development Approach | Bradbury, et al. (2014) |
| 3 | The BIT Model | Mohr, et al. (2014) |
| 4 | The IDEAS Framework | Mummah, et al. (2016) |
| 5 | The mHealth Intervention Development and Evaluation Process | Whittaker, et al. (2012) |
| 6 | The CDE Framework | Johnston, et al. (2015) |
| 7 | The mHealth Intervention Development Process | Smith, et al. (2016) |
| 8 | A Holistic Approach to mHealth Intervention Design | Wang, et al. (2017) |
| 9 | The Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps | Geuens, et al. (2016) |

The (preliminary) critical review revealed several key findings concerning the strengths, limitations and knowledge gaps of current holistic multi- and interdisciplinary approaches relevant to the design of mHealth (physical activity) behaviour change intervention apps. As a first off, the composition and structure of the reviewed approaches held similarities in terms of following a general process flow, from problem/conceptualisation to design, development and evaluation. Differences, however, were apparent in that some approaches viewed the concept of design from a weightier health behavioural sciences perspective (such as Van Gemert-Pijnen, et al., 2011), while others viewed the concept of design from a weightier information systems perspective (such as Mohr, et al., 2014; Geuens, et al., 2016). Viewing mHealth behaviour change intervention app design from one predominant or weightier perspective can be to the detriment of the other perspective, thereby underestimating the value of the one side's contributions to the process and product outcome. A few approaches, though, were able to view design from both a health behavioural sciences and information systems perspective (for example, Mummah, et al., 2016; Smith, et al., 2016; Wang, et al., 2017).

Differences were also apparent in that some approaches viewed the concept of development from a weightier health behavioural sciences perspective (such as Van Gemert-Pijnen, et al., 2011), while others viewed the concept of development from a weightier information systems perspective (such as Mohr, et al., 2014; Geuens, et al., 2016). The concept of development tends to be interpreted as synonymous with implementation in some approaches (such as Whittaker, et al., 2012; Bradbury, et al., 2014; Johnston, et al., 2015; Mummah, et al., 2016), whereas development is interpreted as distinctly different to implementation in other approaches (such as Van Gemert-Pijnen, et al., 2011). An ambiguous understanding of terminology such as development and implementation between the two perspectives can create miscommunications and misunderstandings in multi- and interdisciplinary collaborating teams.

Similarly to the concepts of design and development, the concepts of testing and evaluation are at times viewed and interpreted differently between the different approaches. Testing and evaluation may be viewed in terms of (1) the intervention and its BCTs, (2) the app (as a digital software platform), or (3) both (the intervention and software app platform as one final product). Van Gemert-Pijnen, et al. (2011), for instance, attempts to clarify different interpretations of evaluation by distinguishing between formative evaluation and summative evaluation, where the former pertains to prototyping measures and the latter pertains to clinical measures. As discussed earlier in reference to Figure 4.6 and Figures 4.7, the concept of

evaluation can be interpreted flexibly between professionals from the health behavioural sciences and information systems perspectives. This same challenge is faced with the concept of testing. Some approaches (such as Bradbury, et al., 2014; Johnston, et al., 2015; Mummah, et al., 2016) view testing in terms of usability and user experience testing, which is from an information systems perspective. Whereas other approaches, at times, view testing in relation to clinical pre-testing and pilot trials, which is from a health behavioural sciences perspective. The term testing can also be used with the concept of piloting, which is also interpreted differently between perspectives. Piloting testing can be interpreted in terms of piloting trials before conducting RCTs (such as Whittaker, et al., 2012; Smith, et al., 2016), which assumes a health behavioural sciences stance. Whereas pilot testing can also be interpreted in terms of usability testing (such as Mummah, et al., 2016), which assumes an information systems stance.

As for summative evaluation, Mohr, et al. (2014) acknowledges the importance of conducting RCTs, but does not explicitly state the need to conduct "gold standard" clinical RCTs (Dick, O'Connor and Heavin, 2017, p.2). Wang, et al.'s (2017) approach fails to acknowledge RCTs in their process's evaluation stage altogether. From a health behavioural sciences perspective, this lack of acknowledgement for gold standard RCTs undermines the value of their expert contributions to measuring the long-term and sustainable health outcomes and effectiveness of mHealth behaviour change intervention apps. Another approach that does not incorporate the need for long-term gold standard RCTs is proposed by Whittaker, et al. (2012, p.16), who suggest conducting "pragmatic RCTs", which are smaller scale at the socioecological community level. Murray, et al. (2016, p.848) explains that well-designed and rigorous RCTs remain an important part of evaluating digital mHealth behaviour change interventions, although they recognise that RCTs are "only one part" of the holistic approach to evaluation. Considering the time constraints regarding mHealth behaviour change intervention app design in general, some researchers propose an isolated and tailored RCT evaluation method that focuses on assessing specific behaviour change intervention strategies and techniques (such as self-monitoring) embodied in the design of a given app (Collins, Murphy and Strecher, 2007; Klasnja, Consolvo and Pratt, 2011; Jacobs and Graham, 2016; Klasnja, et al., 2017).

The above paragraphs have discussed the compositional and structural challenges and limitations of the approaches' processes that became apparent through the critical review. In keeping with a discussion on the approaches' processes, some approaches underscored the importance of user-centred design approaches (such as Van Gemert-Pijnen, et al., 2011;

Johnston, et al., 2015; Mummah, et al., 2016; Smith, et al., 2016; Wang, et al., 2017). On the contrary, some other approaches did not acknowledge the value of user-centred design approaches (such as Bradbury, et al., 2014; Mohr, et al., 2014; Geuens, et al., 2016). On another note, all of the reviewed approaches adopted a somewhat linear process nature, although most argued for a flexible and iterative nature that allows for feedback loops. A few approaches that strongly emphasise the importance of an iterative approach to mHealth behaviour change intervention app design include Johnston, et al. (2015), Mummah, et al. (2016), and Wang, et al. (2017). This iterative approach is largely concerned with the prototyping stage, in which rapid cycles of designing, developing and testing lead to a refined and improved functional (working) app prototype that can then be taken further to evaluate in pilot trials and/or clinical RCTs.

The key themes of theory and evidence were observed in the critical review. All of the approaches, in some shape or form, discuss the importance of theory- and evidence-based processes, tools, frameworks, taxonomies and methods. Whittaker, et al. (2012), Mummah, et al. (2014) and Wang, et al. (2017), for instance, explicitly mention specific evidence-based health behavioural change theories, including SCT, Self-Efficacy Theory, the HBM, and the TTM; all of which were presented and described in Chapter 3, Subsection 3.5.1. For the approaches that discussed BCTs, all of them emphasised the importance of employing and incorporating BCTs that are theory- and evidence-based. Some approaches even included specific frameworks that can be used for end user testing, such as Smith, et al.'s (2016) acknowledgement of the Health IT Usability Evaluation Model (Health-ITUEM) (Brown, et al., 2013). A few other approaches referenced specific frameworks for health behaviour change intervention design, such as Smith, et al.'s (2016) mention of Michie, van Stralen and West's (2011) Behaviour Change Wheel (BCW).

Another key theme that became apparent from the critical review concerns behaviour change techniques (BCTs). Most approaches incorporated activities that pertain to the determination, selection and integration of BCTs in the intervention and final app product (such as Bradbury, et al., 2014; Mohr, et al., 2014; Mummah, et al., 2016; Smith, et al., 2016; Wang, et al., 2017). In contrast, a few approaches failed to acknowledge BCTs altogether (such as Van Gemert-Pijnen, et al., 2011; Johnson, et al., 2015). As already discussed throughout this chapter (and in prior Chapter 3), it is necessary and important that intervention designers be provided with guidance in determining, selecting and integrating theory- and evidence-based BCTs into

mHealth apps, particularly since they have shown to be important to the success of mHealth intervention apps. Of the approaches that discussed BCTs, all of them suggested utilising and drawing from Michie, et al.'s (2011; 2013) CALO-RE and v1 BCT taxonomies (as initially presented and discussed in Chapter 3, Subsection 3.5.3).

An additional key theme that became apparent from the critical review concerns persuasive technology, and more specifically, PSD principles. Some of the approaches did not acknowledge the power persuasive technology and PSD principles can have in changing individuals' attitudes and behaviours towards their own health and wellbeing. These approaches included Whittaker, et al. (2012), Bradbury, et al. (2014), Johnson, et al. (2015), and Mummah, et al. (2016). On the contrary, some approaches did acknowledge and emphasise the contribution and value of incorporating persuasive technology and PSD principles into mHealth behaviour change intervention app design and development, arguing that it leads to more persuasive, engaging and successful mHealth apps. These approaches included Van Gemert-Pijnen, et al. (2011), Mohr, et al. (2014), Geuens, et al. (2016), and Wang, et al. (2017). Interestingly though, upon critical review, it was found that Smith, et al.'s (2016) approach acknowledges the power of persuasion, but views and interprets persuasion from a heath behavioural sciences perspective, rather than an information systems perspective, which in matter of fact, is the arena from which persuasive technology and PSD principles stem. Smith, et al. (2016) is not alone in this alternative interpretation. Yardley, et al. (2015a) also views persuasion from a health behavioural sciences perspective in their Person-Based Approach. This again points to challenges concerning interpretive flexibility and different interpretations and meanings of the same terminology between professionals from both perspectives.

In keeping with discussions on BCTs and PSD principles, very few approaches provided pragmatic guidance for translating and operationalising BCTs and PSD principles into software app (user interface) design elements and features. For example, in terms of BCTs, Whittaker, et al. (2012) acknowledges the importance of BCTs, but fails to provide practical guidance for translating and operationalising BCTs into mHealth app design elements or features. Similarly, for example, Van Gemert-Pijnen, et al. (2011) acknowledges the importance of persuasive technology and PSD principles, but lacks the provision of practical guidance for translating and operationalising PSD principles into mHealth app design elements or features. This lack of guidance for translating and operationalising BCTs and PSD principles is well documented in the knowledge base (Geuens, et al., 2016; Direito, et al., 2018; Geuens, et al., 2019a; Wang,

et al., 2019). In an attempt to address this known knowledge gap, Mohr, et al.'s (2014) BIT Model proposes an accompanying BIT-Tech Framework. The BIT-Tech Framework aims to support and assist the instantiation process, in translating the conceptual intervention design into a BIT (behavioural intervention technology) design, and subsequently into a digital interactive and functional app design. In other attempts to address this known knowledge gap, Geuens, et al. (2016) propose an online tool for providing mHealth behaviour change intervention app designers with guidance in translating and operationalising BCTs and PSD principles into digital app (user interface) design elements and features. Geuens, et al. (2016) also details the links between: (1) underlying psychological theoretical constructs (such as SCT, SDT, ELM, HBM, TTM, TRA and TPB); (2) guiding questions and suggestions that designers and developers can ask themselves when translating and operationalising BCTs and PSD principles; and (3) text and illustrative screenshot examples from real mHealth physical activity apps.

In continuing to keep with discussions on BCTs and PSD principles, some approaches (such as Mohr, et al., 2014) distinguish between BCTs and PSD principles as different things, the former of which stems from the health behavioural sciences perspective, and the latter of which stems from the information systems perspective. In sharp contrast to this, Geuens, et al. (2016), Wang, et al. (2017) and (Fadhil and Wang, 2019) view BCTs and PSD principles as somewhat comparable, synonymous and interchangeable. This view leads both Geuens, et al. (2016) and Wang, et al. (2017) to propose consolidated taxonomies that merge BCTs (from the two BCTs taxonomies) with PSD principles (from the PSDM). Fadhil and Wang (2019) even present a BCT-PSD mapping diagram. Upon critical review, this consolidation process exhibits pros and cons. On the one hand, Wang, et al. (2017, p.1), for instance, classify the BCTs taxonomies as a form of "technological model and framework", which is a misassumption and is inaccurate. The reason for this is that the BCT taxonomies originate from the health behavioural sciences perspective and were developed specifically by researchers in the fields of "psychological theory", "health sciences research" and "health psychology" (Michie, et al., 2005, p.26; Michie, et al., 2011; 2013). In other words, the BCT taxonomies stem from the health behavioural sciences perspective and hence cannot be classified under a "technological model and framework" category as Wang, et al. (2017, p.1) does. On the other hand, Geuens, et al. (2016), as like Wang, et al. (2017), consolidate and merge BCTs and PSD principles into an amalgamated taxonomy; however, Geuens, et al. (2016) maintains a respect for their different underlying perspectives. This respect for one another's disciplines, paradigmatic assumptions,

perspectives, knowledge, skills and expertise is imperative in the multi- and interdisciplinary collaborative team design, development and evaluation process. A lack of respect for one another's backgrounds and what they can contribute to the overall design of mHealth behaviour change intervention app projects can have negative effects on the collaborative process and product outcome (Hermsen, et al., 2020).

In moving to another point, some of the holistic multi- and interdisciplinary approaches in this critical review have been utilised and applied in guiding the design of mHealth intervention apps for physical activity behaviour change in particular. Mummah, et al.'s (2016) IDEAS Framework has been used to guide the design, development and evaluation of *PuzzleWalk*, a gamified physical activity app for adults with autism spectrum disorder (Lee, et al., 2018b; Kim, et al., 2020; Lee, et al., 2020). Whittaker, et al.'s (2012) mHealth Intervention Development and Evaluation Process has been used in the design, development and evaluation of *ActiveCoach*, a physical activity app for lower-educated working young adults (Simons, et al., 2018). Johnston, et al.'s (2015) CDE Framework was used together with the PDSA (Plan, Do, Study, Act) cycle to design, develop and evaluate *Inspirun*, a personalised physical activity app for recreational running (Vos, et al., 2016). Mohr, et al's (2014) BIT Model and BIT-Tech Framework were employed by Direito, et al. (2018) to inform the design and development of *TODAY*, an app for reducing sedentary behaviour and increasing physical activity in insufficiently active adults (that is, insufficiently active in terms of the WHO's guideline recommendations).

Generally speaking, each of the nine approaches in this (preliminary) critical review had strengths, limitations and knowledge gaps. These strengths, limitations and knowledge gaps are discussed in more detail in Appendix F, and present opportunities for future research. Notably though, none of the nine approaches in this (preliminary) critical review went into detail about discussing the multiple heterogeneous disciplines involved in mHealth behaviour change intervention app projects, and only a few acknowledged the different relevant disciplines (such as Van Gemert-Pijnen, et al., 2011). In addition, most of the approaches provide guidance by mentioning specific tools, artefacts and methods that collaborating teams can use when designing, developing and evaluating mHealth behaviour change intervention apps. In terms of methods, for example, Bradbury, et al. (2014) make reference to two types of usability testing, namely think-aloud interviews and retrospective interviews, and Mummah, et al. (2016) mention interviews, questionnaires, focus groups, design thinking, and user

experience design testing. However, while some of the approaches mention some tools, artefacts and methods, none of the nine approaches provide a richer "toolbox" from which mHealth behaviour change intervention app project teams can select various tools, artefacts and methods to refer to and utilise during the collaborative design, development and evaluation process. This sheds light on a current knowledge gap and offers an opportunity for future research and new knowledge contributions. Furthermore, in terms of the design, development and evaluation process as a whole, all of the approaches exhibited limitations and gaps, highlighting the ongoing need for holistic multi- and interdisciplinary collaborative approaches that incorporate all necessary and relevant stages of the process. Moreover, none of the nine approaches address challenges and issues pertaining to knowledge sharing and the need for professionals from both the health behavioural sciences and information systems perspectives to strengthen shared understandings, shared viewpoints and the common ground required for negotiating conflicts of interest and bridging knowledge differences (Carlile, 2002; Perski, et al., 2017). All of these limitations demonstrate the ongoing need for better and more comprehensive holistic and multi- and interdisciplinary approaches for guiding collaborative mHealth behaviour change intervention app teamwork.

Overall, despite some holistic multi- and interdisciplinary approach contributions to the knowledge base, it is apparent through the above (preliminary) critical review discussion that the challenges associated with the collaborative design of persuasive and effective mHealth behaviour change intervention apps remains complex and ongoing. mHealth behaviour change intervention app design, development and evaluation is "increasingly a multidisciplinary process" that Hermsen, et al. (2020, p.264) explain requires better multidisciplinary cooperation, reduced barriers to multidisciplinary collaborative interactions and teamwork, better shared understandings, shared visions, shared methodologies and "good knowledge transfer between participating disciplines". The need for establishing shared understandings and common ground in mHealth app project multi- and interdisciplinary collaborating teams is advocated for by others, such as Heffernan, et al. (2016) and Blandford, et al. (2018), who stress the importance of working through these issues and the complexities associated with multi- and interdisciplinary teamwork.

There is an ongoing need for multi- and interdisciplinary collaborations between professionals from the health behavioural sciences and information systems perspectives, and between specialists from various heterogeneous specialisations within these broader perspectives

(Knittle, et al., 2016; Taj, Klein and van Halteren, 2019; Chatterjee, et al., 2021). Bendtsen, et al. (2020, p.1) accentuate that the process of designing, developing and evaluating mHealth behaviour change interventions is "complex" and that it "requires large interdisciplinary teams with competence in technology, behavioural science and lifestyle-specific areas". In a study on mHealth behaviour change intervention consumer apps for physical activity in particular, Bondaronek, et al. (2018, p.11) draw attention to the importance of the "inclusion of multidisciplinary skills and perspectives" when designing and developing such products. Likewise, Kowatsch (2019, p.259) emphasises that "the interdisciplinary field of digital health needs to integrate and consolidate perspectives and research findings from various fields" including health behavioural sciences, software engineering and information systems. Similarly, Knittle, et al. (2016, p.269) highlight that "partnerships between [health] behavioural science and HCI [information systems] are key to developing and evaluating useful, usable and rewarding digital [mHealth] interventions". Cowan, et al. (2012, p.138) note that, for physical activity apps in particular, "combinations of skills ultimately produce higher quality apps with improved effectiveness". Taj, Klein and van Halteren (2019, p.1) also stress that "closer cooperation and interaction between [health] behavioural sciences and technological areas is needed", that there is a "large [knowledge] gap in the process of designing digital technologies for health behaviour change", and that there "is a lack of design guidelines" for guiding the practical collaborative team process.

Wang, et al. (2017, p.2) further point out that "researchers from both sides are more likely to miss information from the other domain due to lack of exposure and expertise in the domain". Mohr, et al. (2014, p.1) share similar sentiments, explaining that "experts from both fields..." of health behavioural sciences and information systems "…contribute to the development of behaviour change intervention technology, but [that] the vastly different training and knowledge backgrounds have led to differences in conceptual models that guide development and evaluation". Knittle, et al. (2016, p.269) echoes this point by explaining that experts from both sides tend to "use very different language, models and concepts". These differences in paradigmatic worldviews, assumptions, perspectives, knowledge, skills and expertise often lead to challenges in communication and collaborative work in multi- and interdisciplinary teams. For this reason, Stawarz and Cox (2015, p.3), Schoeppe, et al. (2017), Blandford (2019a) and Hermsen, et al. (2020) emphasise that researchers and practitioners can "learn from other fields" by remaining willing, open and respectful of one another's backgrounds and training. Knittle, et al. (2016, p.269) mirrors this argument, highlighting that "successful collaboration

requires an openness to learning about each other's concepts and terminology, ways of working and incentives, as well as knowing what each field brings to the table in terms of evidence, theories and methods". Knittle, et al. (2016, p.269) also emphasise that while "this process is challenging", collaborative efforts towards "fostering innovative transdisciplinary thinking" and offing "new insights" can yield "great prizes". All in all, the ongoing need for the holistic multi- and interdisciplinary approaches, and better team communication and collaboration, represents a knowledge gap that requires future research and novel perspectives and solutions.

## 4.5 Conclusion

This chapter contributes to answering the first research sub-question by providing an overview of the digital health landscape and positioned the delineated thesis focus within the specialised fields of CHI, mHealth and mHealth consumer apps, giving particular attention to physical activity (health and fitness) apps delivered to individuals at the dual intra-interpersonal socioecological levels of health promotion. After this, a comprehensive discussion covered the main challenges faced in the design of mHealth (physical activity) behaviour change intervention apps. In this first part of this discussion, the two broad health behavioural sciences and information systems perspectives were presented, and an argument was made regarding the need for collaboration and integration between these two perspectives. In the second part, key design challenge themes were outlined, concerning mainly the use and integration of theory, the incorporation of evidence-based BCTs, the application of PSD principles, difficulties with interpretive flexibility, and the importance of multi- and interdisciplinary collaborative design, development and evaluation approaches/processes; all of which influence the effectiveness of mHealth (physical activity) behaviour change intervention apps.

The third part of the comprehensive discussion was divided into two further subsections, providing a more detailed discussion on the challenges and opportunities associated with approaches and processes for guiding the multi- and interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps. The first sub-subsection explained the similarities and differences between the approaches and processes that are typically used by the two broad perspectives, and emphasised the ongoing need for holistic multi- and interdisciplinary approaches and processes that aim to bridge the divide between these two perspectives. The second sub-subsection included a (preliminary) critical review of nine existing holistic multi- and interdisciplinary approaches, and discussed key strengths, limitations and challenges associated with these approaches, as

well as knowledge gaps and opportunities for future research. Some key challenges and knowledge gaps concern: the structure and nature of current multi- and interdisciplinary approaches; the use of different methods, frameworks, tools and taxonomies; misunderstandings and miscommunications that often arise from the unexpressed interpretive flexibility of certain terms/concepts; and the lack of practical guidance for translating and operationalising BCTs and PSD principles into engaging app design features. Another issue concerns interdisciplinary collaborative team composition and functioning, and the importance of mutual respect and trust for each member's perspectives, assumptions, interests, motives, theories, approaches, methods, and expert contributions to mHealth (physical activity) behaviour change intervention app design, as well as a willingness to learn from one another in order to advance the emerging field. An additional knowledge gap concerns the lack of provision of "toolboxes" (identifying various tools, artefacts and methods that teams can select from to use during the mHealth app design, development and evaluation process). Furthermore, there is a need for better guidance and support in terms of interdisciplinary knowledge sharing and team communication, so that teams can better establish shared understandings and common ground to bridge differences in perspectives and overcome conflicts of interest. Essentially, the overall discussion on the key challenges associated with the design of mHealth (physical activity) behaviour change intervention consumer apps closes with several quotes from recent literary publications to corroborate the relevance and significance of the main thesis problem addressed in this research project. Figure 4.8 provides a graphical overview of the funneled digital health landscape discussion in this chapter; building on the topic and context foundation from Chapter 3 and honing in specifically on the thesis problem addressed in this research project (colours in Figure 4.8 do not denote specific meanings other than to distinguish each funnel layer; icons correspond to respective labels for each funnel layer).

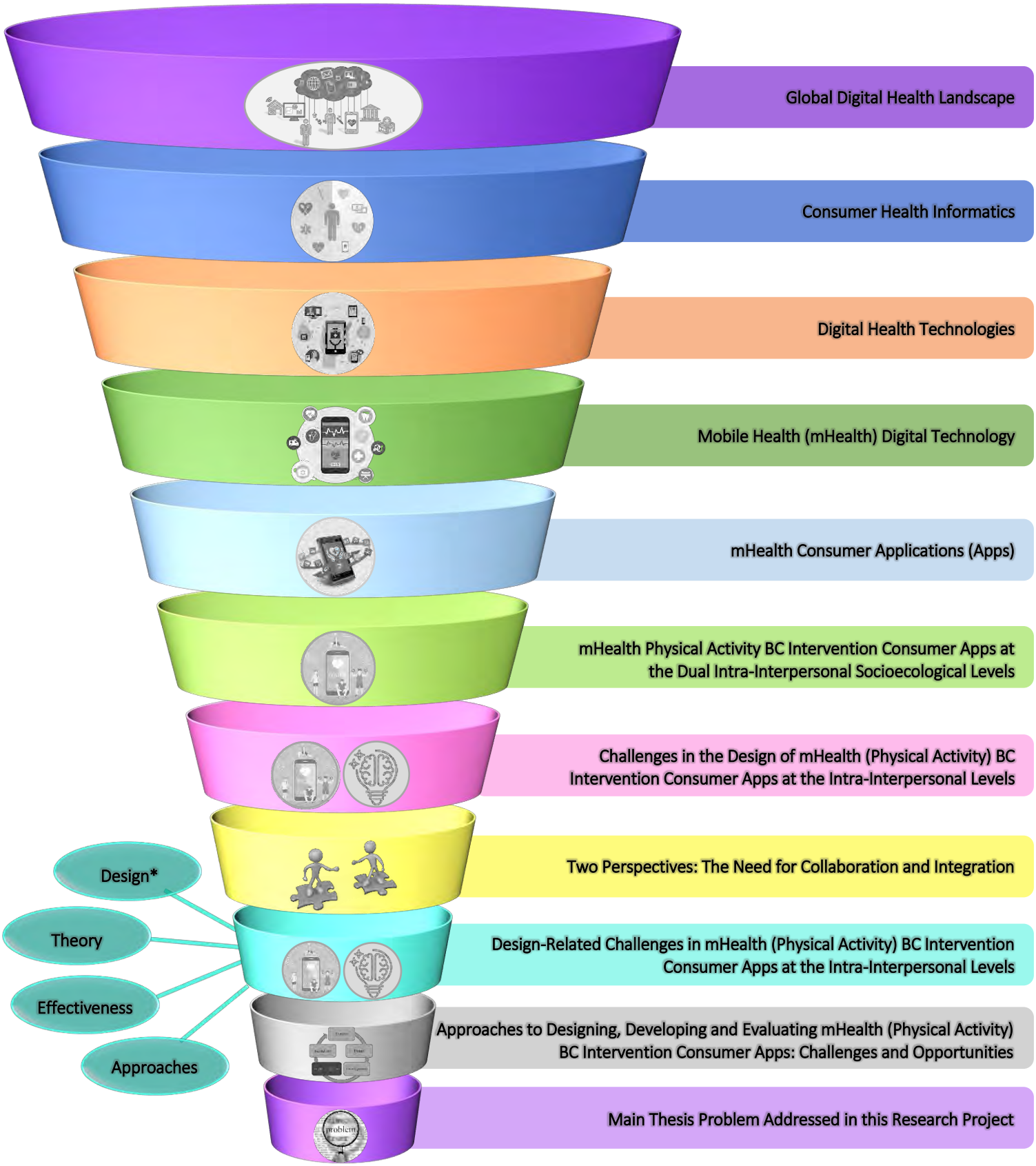



*Figure 4. 8: Funneled Overview of Digital Health Landscape: Research Project Topic and Context Foundation, and Thesis Problem [Source: Researcher's own construction]*

*Design* mainly covers BCTs, PSD Principles, Adoption/Engagement Usage and Gamification*

# Chapter 5

## A Boundary Object View to the Interdisciplinary Collaborative Design of mHealth Behaviour Change Intervention Apps

*The boundary object concept [provides] a theoretical guideline of how to deal with a real world problem as a common focus point for interdisciplinary research.*

*– Feldhoff, et al. (2019, p.4) –*



## 5.1 Introduction

Designing mHealth behaviour change intervention apps is a challenging and multidimensional heteropraxial activity requiring involvement, knowledge and contributions from a diverse range of specialists situated across several disciplinary domains (Peiris, Miranda and Mohr, 2018; Blandford, 2019; Sellak and Grobler, 2020). The growing calls for multi- and interdisciplinary approaches to better guide and support the collaborative design, development and evaluation process between relevant heterogeneous parties (Blandford, et al., 2018b; Hermsen, et al., 2020; Sucala, et al., 2020; 2021) reveals the need for innovative solution perspectives. Novel perspectives can offer new ways of bridging the divide between the two broad health behavioural sciences and information systems perspectives, and can help address the challenges associated with design knowledge sharing and design praxis (presented and discussed in Chapter 4).

This chapter starts with a succinct moulding of the thesis problem and justifies the significance and need for new multi- and interdisciplinary collaborative approaches to guide the collaborative design of effective mHealth (physical activity) behaviour change intervention apps. Thereafter, a tri-composite theoretical framework – comprising community of practice theory, boundary object theory and knowledge boundary theory – is proposed as a novel perspective to addressing the defined problem. Concisely referred to as the *boundary object view*, these three theories and their core constructs are described in detail, along with justifications and examples evidencing their relevance and applicability as new theoretical lenses for addressing the problem. Following this, the boundary object view is defended in its suitability and applied use within the information systems discipline, the pragmatic paradigm and the DSR methodology, after which the chapter is concluded.

The main aim of this chapter is to introduce and justify a novel solution perspective to address the paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps. As illustrated in Figure 5.1, proposing a novel solution perspective falls within Step 2 ("suggestion (tentative design)") of the study's DSRM (outlined in Chapter 2). This chapter lays the theoretical foundation for answering the third research sub-question: *"How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*.

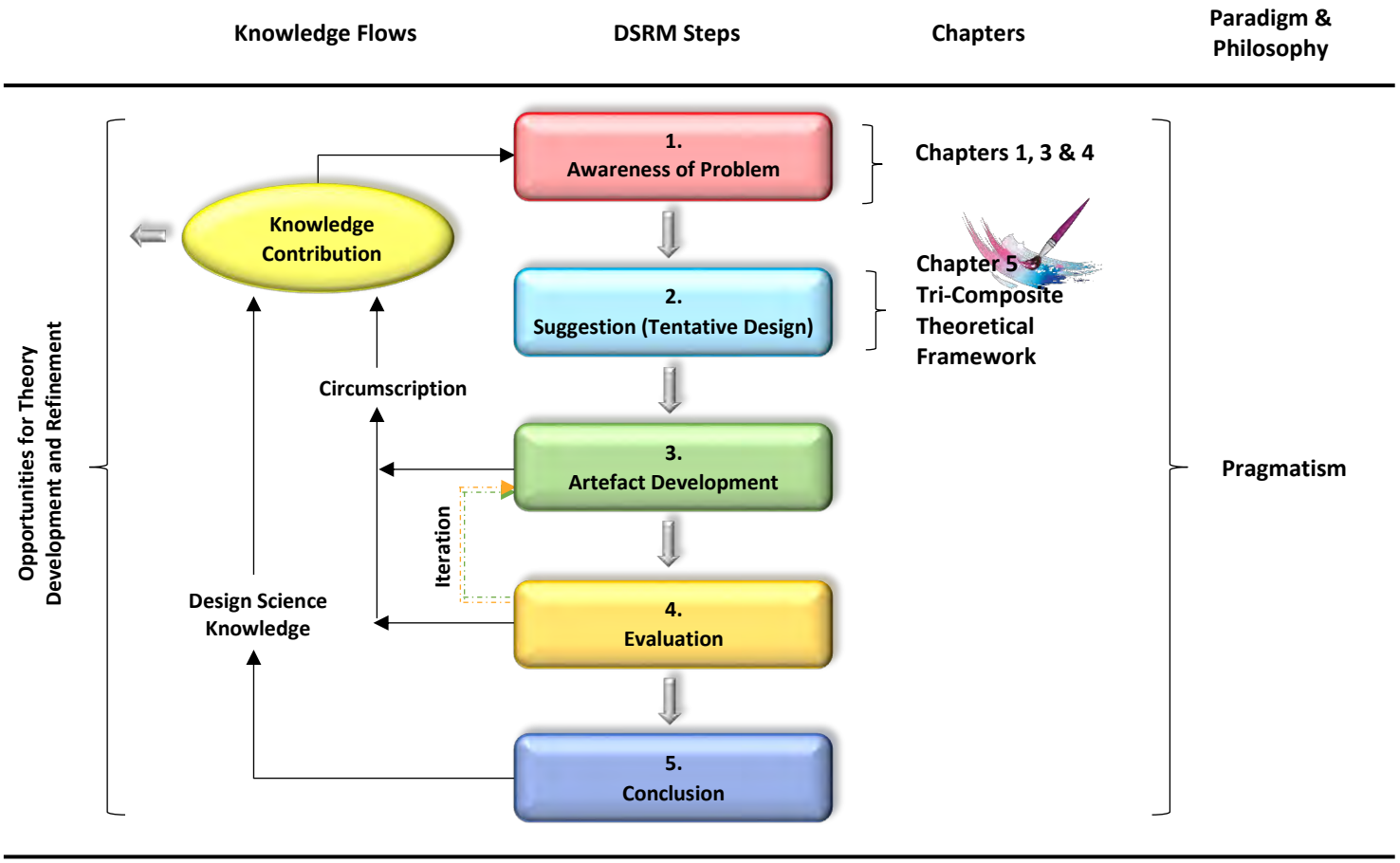



*Figure 5. 1: DSM: Proposing a Suggestion (Tentative Design Solution) [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 5.2 The Importance of an Interdisciplinary Collaborative Approach to Designing mHealth Behaviour Change Intervention Apps

The multidimensional complexities and design challenges concerning the integration of theory, incorporation of behaviour change techniques (BCTs), application of persuasive systems design (PSD) principles, and difficulties with interpretive flexibility, amongst other challenges, presents a "wicked", intricately interwoven and compounded design problem (Rittel and Webber, 1973, p.160; Hevner and Chatterjee, 2010, p.11). The multifaceted design related challenges, in addition to issues regarding development, formative testing and evaluation, sheds light on a knowledge excavation site that requires expertise, skill, practice and knowledge contributions from a heterogeneity of relevant disciplines, all of which are necessary and important for the collaborative and improved production of effective mHealth consumer apps. Whilst each contributing discipline and specialisation is independent in its own right, mHealth

behaviour change intervention apps represent a shared interdisciplinary problem and solution space that requires ongoing communication, coordination, cooperation and collaboration between the relevant, albeit diverse, contributing parties.

In response to the calls for multi- and interdisciplinary approaches to digital and mHealth intervention design, several approaches have been proposed within recent years, such as *the Digital Intervention Development Approach*, *the IDEAS Framework*, *the mHealth Intervention Development Process*, and *the Holistic Approach to mHealth Intervention Design*, to name a few (critically reviewed in Chapter 4, Subsection 4.4.3.2). Despite these recent contributions to the knowledge base, issues rooted in the collaborative design, development and evaluation of mHealth behaviour change intervention apps remains a key challenge in the "young" (Mummah, et al., 2016, p.1) and "emerging interdisciplinary [mHealth] field" (Taj, Klein and van Halteren, 2019, p.1). The ongoing paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps influences the process efficiency, project success and output product effectiveness of said apps (Sellak and Grobler, 2020; Sucala, et al., 2020). Moreover, none of the proposed approaches currently existing in the knowledge base leverages the potential of objects and artefacts as a useful means for facilitating and mediating knowledge sharing and heteropraxial praxes between collaborating team members on mHealth behaviour change intervention app projects.

## 5.3 A Novel Perspective: A Boundary Object View to the Interdisciplinary Collaborative Design of mHealth Behaviour Change Intervention Apps

Boundary object theory, which interlaces with community of practice theory and knowledge boundary theory, offers a novel perspective to addressing the lack of guidance and support for interdisciplinary collaborating teams of mHealth (physical activity) behaviour change intervention app projects. Rooted in pragmatism and sociomaterialism, the three theories together constitute a tri-composite theoretical framework – concisely referred to as the boundary object view – which illuminates the value of objects and design artefacts as tools for facilitating and mediating heterogeneous knowledge and heteropraxial activities across collaborating parties (Bertelsen, 2000; Carlile, 2002; 2006; Doolin and McLeod, 2012; Carlile, et al., 2013; Huvila, et al., 2016; Caccamo, 2020). In other words, conceptual and material objects can help guide and support interdisciplinary collaborating teams throughout the

mHealth app design, development and evaluation process, and can provide teams with a pragmatic means of communicating and sharing knowledge across heterogeneous disciplinary boundaries.

The following three subsections introduce and comprehensively describe each of the three kernel theories (Gregor and Jones, 2007; Iivari, 2020), particularly in terms of their seminal origins and their applicability as theoretical lenses for informing the development of a novel DSR solution artefact (Baskerville, et al., 2018). Example applications of these theories, relevant to information systems, design and collaborative processes are supplied, as well as some critiques and limitations of each theory.

### 5.3.1 Community of Practice Theory

Each heterogeneous contributing team member involved in the interdisciplinary collaborative design, development and evaluation of mHealth behaviour change intervention apps represents and operates from a different community of practice. The term *community of practice* originates from anthropological and sociological theory (Lave, 1988; Wenger, 2010) and has been extended into systems theory (Wenger, 1998; 2000) to describe a self-selecting and self-managing community of people who share a joint area of interest, communicate and interact regularly, and share common perspectives and approaches (including shared language, norms, methods, tools and artefacts). More simply put, a community of practice refers to a group of individuals within a specific discipline or specialised domain who share knowledge and adopt a shared mental model or "shared worldview" in interpreting, understanding and making sense of reality (Gasson, 2005, p.6; Fong, Srinivasan and Valerdi, 2007). Different communities of practice hold different worldview perspectives that inform their distinctive shared repertoire of communal resources, identifiable through their vocabulary, norms, culture, theories, tacit knowledge, interpretations, values, praxes and processual activities (Wenger, 1998; Shapiro, 2020). Figure 5.2 and Figure 5.3 provide illustrative examples of two and four separate communities of practice, respectively, where each practice community holds shared worldview perspectives within their own community, but exhibit differences in worldview perspectives between heterogeneous communities. In Figures 5.2 and 5.3, the number of community practice actors is irrelevant; the intention is to convey their practice community grouping and differences in perspectives.

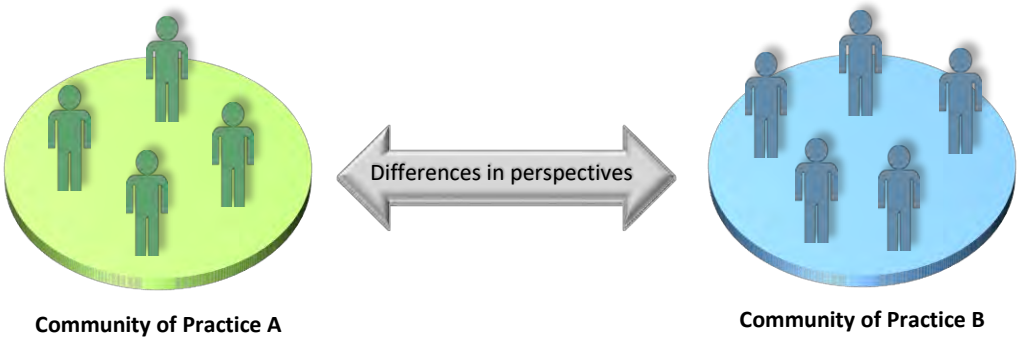



*Figure 5. 2: Two Communities of Practice, Communities A and B, Holding Differences in Worldview Perspectives [Source: Researcher's own construction, informed by Wenger (1998; 2000) and Fong, Srinivasan and Valerdi (2007)]*

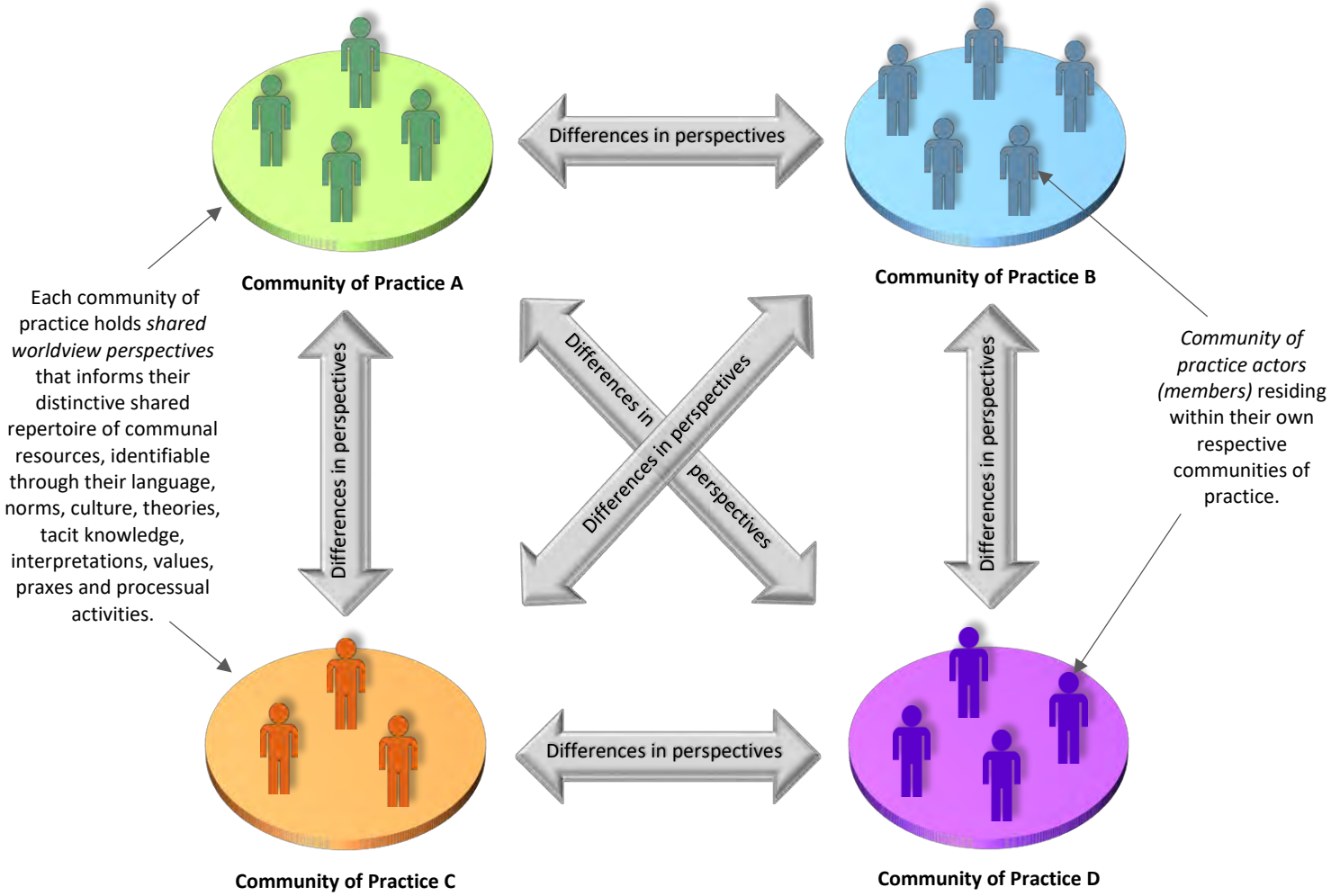



*Figure 5. 3: Four Communities of Practice, Communities A, B, C and D, Holding Differences in Worldview Perspectives [Source: Researcher's own construction, informed by Wenger (1998; 2000) and Fong, Srinivasan and Valerdi (2007)]*

The pragmatic concept of communities of practice is similar to Strauss's (1978, p.119) and Star and Griesemer's (1989, p.388) sociological and symbolic interactionist concept of "social worlds", which is utilised in seminal boundary object theory to refer to human behavioural and social organisation systems that unite actors by virtue of their shared worldview perspectives and mutual interests. The pragmatic adaption, however, is different in that it extends beyond the concept of social worlds to account for actors' shared constellations of practices (Wenger, 1998; 2000). This pragmatic view emphasises the notion of *practice*, and highlights what social actors actually *do* together when collaboratively learning and performing practices as well as what they produce as a result of their collaborative joint practices (Wenger, 1998; 2000). Furthermore, the abstract concept of social worlds denotes social affiliation, whereas the pragmatic concept of communities of practice conveys membership ties established through real-world practice communication, participation, coordination, cooperation and collaboration (Cabitz, 2015). Moreover, the concept of practice does not imply an atheoretical stance, but instead describes the pragmatic application and realisation of theory through real-world recurrent activities (Orlikowski, 2000).

The heterogeneous communities of practice relevant to the design, development and evaluation of mHealth (physical activity) behaviour change intervention apps each have their own ways of thinking, ways of seeing the world, ways of making sense of design problems and solutions, ways of doing and practising activities, and ways of relating to, communicating and collaborating with one another. These different ways of being and practising become strikingly apparent and discernible when actors from diverse backgrounds are required to traverse beyond the boundaries of their own practice communities in order to collaborate in intersecting interdisciplinary spaces with actors from other backgrounds. Obstacles and conflicts often arise when actors' divergent perspectives and practices are in discordance with one another, creating central tensions amongst collaborating parties (Star and Griesemer, 1989). The lack of shared mental models between heterogeneous collaborating community practitioners yields mental fragmentations that "may make it impossible for experts from different contexts to 'speak the same language' and exchange ideas about a problem [and solution]" (Engeström, Engeström and Kärkkäinen, 1995, p.321).

Over time, through open communication, active listening and critical reflexion, community practitioners are able to consciously observe, cognitise and understand the diversity of worldview perspectives and praxes within the interdisciplinary collaborating space, thus

affording them the opportunity to escape, change or transform their own perspectives, theories, interpretations, values, goals and practices (Kemmis and Smith, 2008). This points towards another key characteristic of practice communities, namely that they are inherently social learning systems capable of adapting and transforming perspectives, knowledge and praxes over time (Wenger, 2000) leading to more efficient and effective collaborations within interdisciplinary spaces.

In order to bring together divergent worldview perspectives and practices, mend mental fragmentations and create opportunities for interdisciplinary social system learning, heterogeneous actors (team members) of mHealth intervention app projects need to negotiate and devise shared "common interests" (Levina and Vaast, 2005, p.337) and "common goals" (Star and Griesemer, 1989, p.408) that align and harmonise the different communities of practice. In mHealth (physical activity) behaviour change intervention app projects, heterogeneous actors stemming from various specialisations within the health behavioural sciences and information systems perspectives, all offer relevant and valuable knowledge, expertise, skill and practice contributions to the collaborative process and final mHealth consumer app product. The crux of the challenge, however, lies in managing, facilitating and mediating knowledge sharing and heteropraxial practices between these diverse communities of practice, and guiding and supporting their collaborations so that the common goals of the project can be attained.

There are, however, a few challenges and critiques of community of practice theory. A notable challenge is that boundaries between diverse communities of practice are not fixed, but instead are fluid, permeable and continuously shifting and evolving, sometimes making their precise delineations difficult to identify and describe (Roberts, 2006; Shapiro, 2020). Furthermore, with globalisation and the ongoing advancement and infiltration of technology in society, the size and spatial dispersion of communities of practice may range from small groups of people working in close proximity to globally distributed communities, which affects discourse, practice, engagement and membership interaction. On another note, in terms of criticisms, if a community of practice is too rigid in structure and bound to its traditional ways of knowing and practising, it can cultivate a culture that actively avoids learning and transformation, therefore hindering innovation and advancement within the community (Wenger, McDermott and Snyder, 2002). This rigidity often coexists with political pride held by experts in a community who hoard and assume exclusive ownership of their knowledge and practice skills,

leading to outsiders and other community collaborators feeling "hostage to the self-righteous expertise of specialists" (Wenger, McDermott and Snyder, 2002, p.142). These sanctimonious political and power plays can also lead to stagnation in the community of practice when its members refuse to connect, communicate and collaborate with other communities of practice, thereby stunting opportunities for learning, growth and knowledge transformation (Roberts, 2006). Mutual trust and a willingness to share and disseminate tactic knowledge should therefore be engrained in the social and cultural norms of practice communities (Roberts, 2006). This will allow for knowledge and practice transformation both within the community and between diverse communities when collaborating in intersecting interdisciplinary spaces.

Despite these challenges and criticisms, community of practice theory remains a valid, reliable, widely cited and broadly applied theory (Wenger-Trayner, et al., 2015; Mohajan, 2017; Hanschke, et al., 2021). As a theoretical framework, community of practice theory has been applied to an extensive range of contexts. This includes health (Melville-Richards, 2015; French), health psychology and health behavioural intervention sciences (Schott and Hodgetts, 2006), persuasive design and gamification (Lawo, et al., 2020), interdisciplinary projects (Vincent, et al., 2018); physical activity promotion (Harris, Cale and Hooper, 2021); information systems (Damtew, 2013; Abraham, 2015; Shapiro, 2020).

### 5.3.2 Boundary Object Theory

#### 5.3.2.1 What are Boundary Objects?

Boundary objects "sit in the middle" of intersecting communities of practice (Star, 2010, p.608) and provide a valuable means of representing and communicating heterogeneous knowledge and mediating heteropraxial activities across diverse practice community boundaries (Bertelsen, 1998). The term *boundary object* refers to any conceptual (abstract) or material (physical) artefact or "thing" that holds relevance for multiple diverse communities of practice and facilitates communication, coordination, cooperation and collaboration between these communities (Star and Griesemer, 1989; Star, 2010, p.603). In the context of mHealth (physical activity) behaviour change intervention app projects, boundary objects essentially support interdisciplinary collaborating team members' knowledge and practice sharing by providing a "common frame of reference" (Bertelsen, 2000, p.8). Furthermore, boundary objects are often "human constructions" employed or created to act as anchors or bridges for interdisciplinary team members of mHealth intervention app projects to address their conceptual, theoretical and pragmatic fragmentations and to engage in collaborative

problem solving and solution forming activities (Star and Griesemer, 1989; Carlile and Lakhani, 2011, p.3). As the seminal architects of boundary object theory, Star and Griesemer (1989, p.939) define boundary objects as artefacts that:

> "*...inhabit several intersecting social worlds [or communities of practice (Star, 2010, p.604)] and satisfy the informational requirements of each of them... are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use… may be abstract or concrete… [and] have different meanings in different social worlds [or communities of practice (Star, 2010, p.604)] but their structure is common enough to more than one world to make them recognisable, a means of translation."*

Boundary object theory originates from Star and Griesemer's (1989) ecologically orientated adaption and extension of Strauss's (1978) concept of social worlds and symbolic interactionism, and Callon's (1986), Law's (1986) and Latour's (1987) sociological and technological models of interessement (as a process of translation) and actor-network theory (as a material-semiotic approach). After two decades, Star (2010, p.602) described boundary object theory as a "constructivist approach" that views objects from a pragmatic and material perspective.

Over the last thirty-two years, boundary object theory is has been extended and modified to suit an expansive range of contexts. From a health perspective, some contextual applications include health sciences (French, 2016; Wallace, 2020), public health and wellbeing promotion (Wall, 2017), and complex health behavioural interventions (Rousseau, et al., 2019). From a technological perspective, applications include information systems (Levina and Vaast, 2005; Hölttä, 2013; Huvila, et al., 2016), systems design and development processes (Subrahmanian, et al., 2003; Doolin and McLeod, 2012; Rosenkranz, Vranešić and Holten, 2014), human computer interaction (Christiansen, 2005), persuasive systems design (Chasanidou, 2018), and gamification (Khaled and Vasalou, 2014). In terms of design, contextual applications include design theory (Bergman, Lyytinen and Mark, 2007), design artefacts (Bertelsen, 1998; 2000; Johnson, et al., 2017), participatory design (Broberg, 2011; Khaled and Vasalou, 2014) and co-design/co-creation processes (Uppström, 2017; Islind, et al., 2019). At the intersection of

these fields, boundary object theory has also been applied to digital health contexts (McLoughlin, et al., 2016; Islind, et al., 2019).

Boundary object theory has become a universally accepted and reliable theory for addressing real-world complex and "wicked" design problems (Gasson, 2013, p.88), where knowledge and practice sharing challenges often arise due to "mismatches" between heterogeneous community of practice worldview perspectives and praxes (Star and Griesemer, 1989, p.412; Worrall, 2014). In interdisciplinary spaces in particular, sociomaterial and relational interactions with boundary objects allow collaborating team members to contribute their diverse knowledge to the emerging solution design of a mHealth consumer app by facilitating and mediating their active communication, reflexion, learning and negotiation processes (Doolin and McLeod, 2012; Huvila, et al., 2016; Heiss, 2020; Tharchen, Garud and Henn, 2020).

### 5.3.2.2 Using Boundary Objects in Shared Spaces

Boundary objects are used and created by interdisciplinary collaborating actors within the shared boundary space at the overlapping intersection of heterogeneous communities of practice (Star and Griesemer, 1989). While the colloquial interpretation of the concept of boundaries often denotes a periphery or marginal edge, Star and Griesemer (1989) use the term to describe "a shared space" where the "sense of here and there are confounded" (Star, 2010, p.602). Figure 5.4 and Figure 5.5 provide example illustrations of "a shared space" between two and four separate communities of practice, respectively.

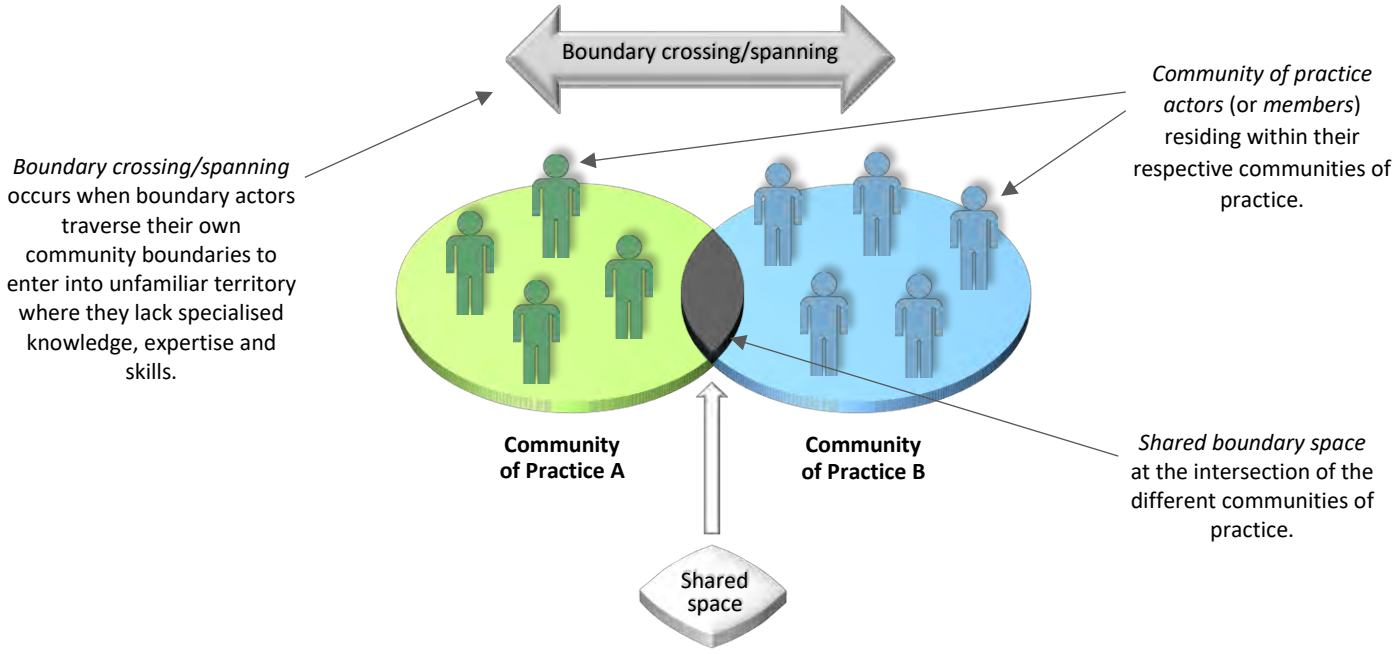



*Figure 5. 4: The Shared Boundary Space between Two Intersecting Communities of Practice, Communities A and B [Source: Researcher's own construction, informed by Wenger (1998; 2000), Levina and Vaast (2005) and Fong, Srinivasan and Valerdi (2007)]*

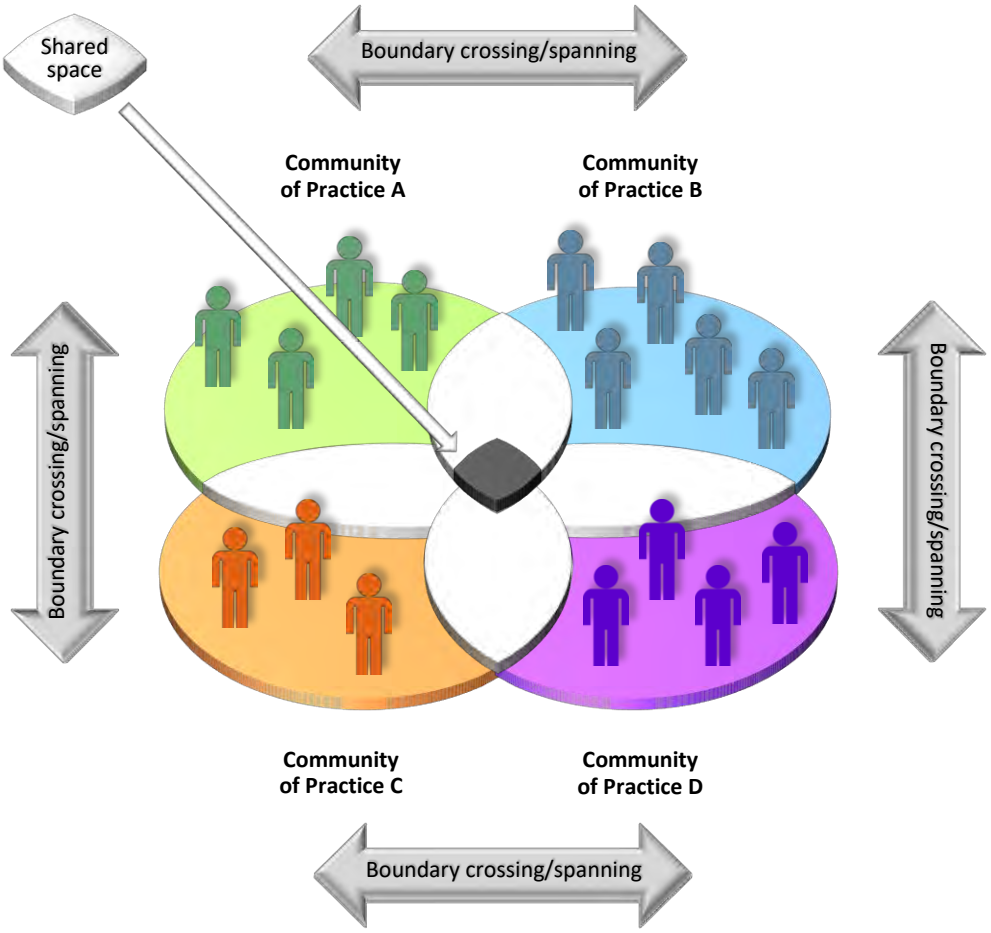



*Figure 5. 5: The Shared Boundary Space between Four Intersecting Communities of Practice, Communities A, B, C and D [Source: Researcher's own construction, informed by Wenger (1998; 2000), Levina and Vaast (2005) and Fong, Srinivasan and Valerdi (2007)]*

Within the shared space, interdisciplinary collaborating actors (team members) engage in boundary crossing (Engeström, Engeström and Kärkkäinen, 1995) and boundary spanning (Levina and Vaast, 2005, p.337) activities, which are the efforts by individuals or groups at the boundaries to establish and restore continuity in interactions and actions across practice communities (Akkerman and Bakker, 2011). Boundary crossing arises as boundary actors depart their localised positioning within their own communities of practice, and traverse their community boundaries to enter into unfamiliar territory in which they, to some extent, lack specialised knowledge, expertise and skills, and are unqualified (Suchman, 1994).

In the shared space, boundaries are generally fluid and indefinite, and become blurred due to their implicit and unspoken nature (Wenger, 2000). Consequentially, shared spaces of interdisciplinary collaboration are often places of potential misunderstandings and conflicts (Wenger, 2000). At the same though, shared spaces are places for learning, where participating actors from the relevant heterogeneous communities of practice are able to reconcile

differences with other communities, develop their expertise, competencies and skills, and where interdisciplinary and transdisciplinary knowledge is fostered and generated (Wenger, 2000; Carlile, 2004). Moreover, the shared space creates an environment where interdisciplinary collaborating team members can use and create boundary objects to establish common ground and engage in perspective-making, perspective-taking, problem solving and innovative heteropraxial design activities to produce effective mHealth behaviour change intervention apps. Therefore, it is imperative that in the shared space, intersecting community of practice actors create a shared common goal, and use appropriate collaborative processes and boundary objects to guide, support and mediate their interdisciplinary efforts towards achieving the final mHealth intervention app product solution.

#### 5.3.2.2 Boundary Actors

In boundary object theory, community of practice actors are synonymously referred to as "boundary workers", "boundary crossers" (Akkerman and Bakker, 2011, p.140), "marginal people" (Star and Griesemer, 1989, p.411) and "boundary spanners" (Levina and Vaast, 2005, p.338). Levina and Vaast (2005, p.339) further distinguish between "nominated boundary spanners" (actors who are designated and assigned certain boundary spanning roles and activities) and "boundary spanners-in-practice" (actors who, with or without nomination, emerge organically). Boundary workers are actors that temporarily traverse their own community boundaries to engage in boundary crossing/spanning activities and knowledge sharing with boundary workers from other communities for the duration of collaborative projects, but they remain localised and committed to their home communities (Rosenkranz, Vranešić and Holten, 2014). Sometimes boundary workers/spanners are erroneously referred to as "boundary brokers" (Akkerman and Bakker, 2011, p.140); two different roles that should be distinguished (Levina and Vaast, 2005; Rosenkranz, Vranešić and Holten, 2014).

Boundary brokers, in contrast to boundary workers/spanners, are not localised within or committed to specific communities of practice (Rosenkranz, Vranešić and Holten, 2014). Boundary brokers are "weakly linked to several communities" yet they are "full members of none" (Rosenkranz, Vranešić and Holten, 2014, p.310). Brokers operate from a neutral, impartial and objective standpoint, and engage in brokering activities that facilitate transactions and knowledge "traffic" between intersecting and collaborating communities of practice (Pawlowski and Robey, 2004; Meyer, 2010, p.120). Brokers support the establishment of cross- and interdisciplinary communication, coordination, cooperation and collaboration, and

perform "import-export" activities (Wenger, 1998, p.109) that create opportunities for learning and knowledge transformation in cultivating the emergence of "new joint field[s]", such as the burgeoning field of mHealth behaviour change intervention apps (Levina and Vaast, 2005, p.339; Meyer, 2010). Brokers also assume managerial, intermediary and leadership roles in guiding and supporting boundary workers/spanners on collaborating projects towards achieving their shared common goal (Rosenkranz, Vranešić and Holten, 2014). Figure 5.6 provides an illustrative example of a boundary broker (denoted by the neutral black actor icon) and boundary workers/spanners who traverse their own community of practice boundaries to engage in collaborative boundary crossing/spanning activities within a shared boundary space.

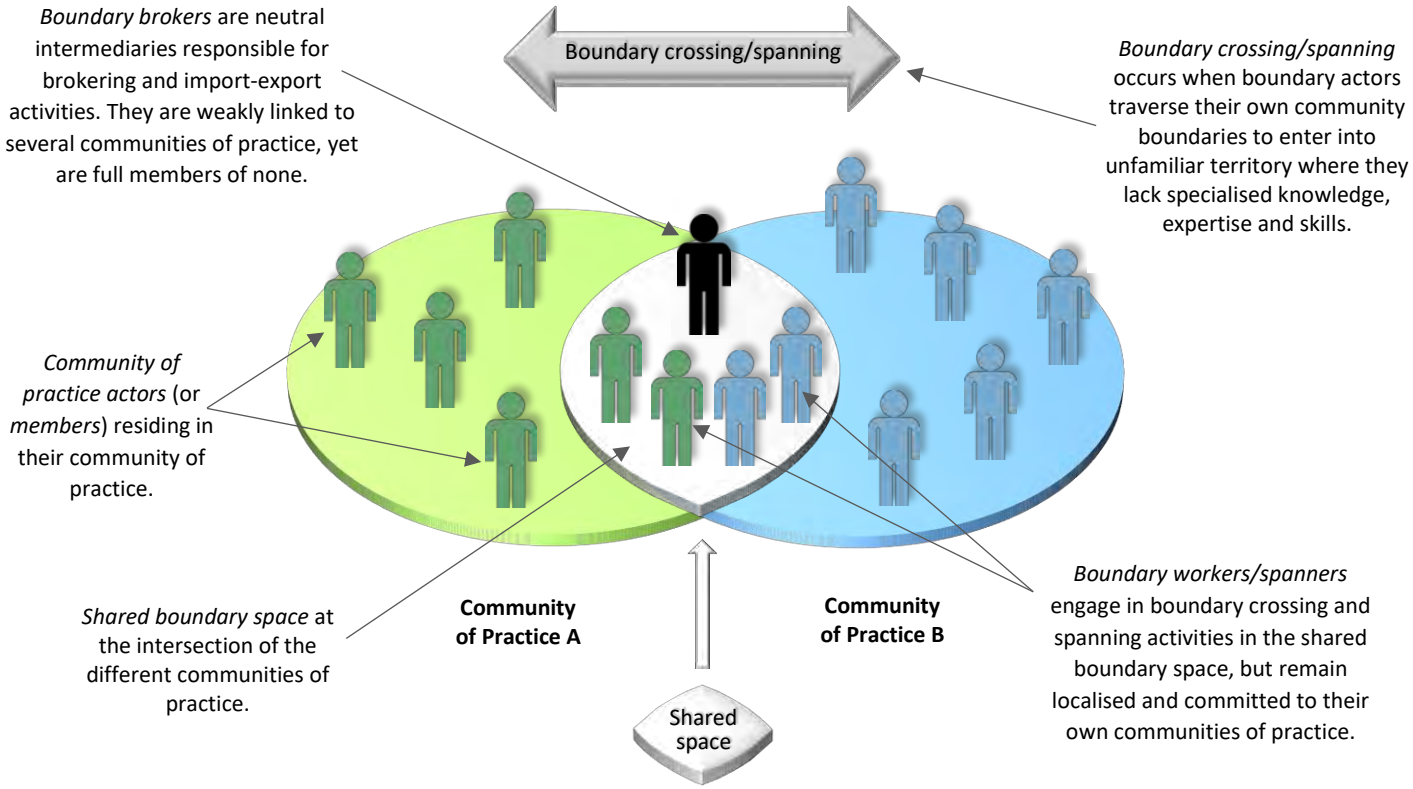



*Figure 5. 6: Boundary Brokers and Boundary Workers/Spanners Collaborating in a Shared Boundary Space, Communities A and B [Source: Researcher's own construction, informed by Wenger (1998; 2000), Levina and Vaast (2005) and Rosenkranz, Vranešić and Holten, 2014)]*

Notably, although the roles and responsibilities of boundary brokers and boundary workers/spanners are distinguishable, both types of boundary actors face challenges when establishing themselves as human bridges between heterogeneous communities of practice, and when engaging in collaborative boundary crossing/spanning activities in order to attain shared

mHealth intervention app project and product goals. Star and Griesemer (1989) point out that boundary actors need to learn and employ strategies for managing their shifting identities when traversing practice community boundaries. Williams (2012) echoes this challenge, and sheds light on the ambiguities, paradoxes and tensions encountered and experienced by boundary actors when engaging in boundary crossing/spanning activities in shared spaces. To overcome these challenges, Williams (2012) highlights the importance of possessing competencies associated with negotiation, diplomacy, flexibility and interpersonal skills such as trust, empathy and conflict management.

On a networking level, there is a risk that boundary actors inadvertently function as bottlenecks, or unintentionally withhold, distort or miscommunicate knowledge and information that can hinder the efficiency and effectiveness of the interdisciplinary collaborative process (Long, Cunningham and Braithwaite, 2013). Moreover, on a personal level, boundary actors often carry additional costs to their wellbeing due to work overload, stress and burnout (Long, Cunningham and Braithwaite, 2013). On a political level, another difficulty concerns the ongoing surfacing and challenging of worldview assumptions and perspectives, the relinquishing of knowledge ownership (in order to transform knowledge and praxis) (Pawlowski and Robey, 2004) and the political manoeuvring encapsulated in brokering and spanning practices (Rosenkranz, Vranešić and Holten, 2014). This political function refers to the collaborating team's power structures and dynamics regarding a mHealth behaviour change intervention app project and product, which determines which boundary actors have the power to make final design decisions, and which actors control the resources and objects mobilised throughout the design, development and evaluation process (Bergman, Lyytinen and Mark, 2007). As facilitation and mediation artefacts, boundary objects play an important role in addressing and overcoming political challenges in interdisciplinary collaborating teams (Carlile, 2004; Feldhoff, et al., 2019).

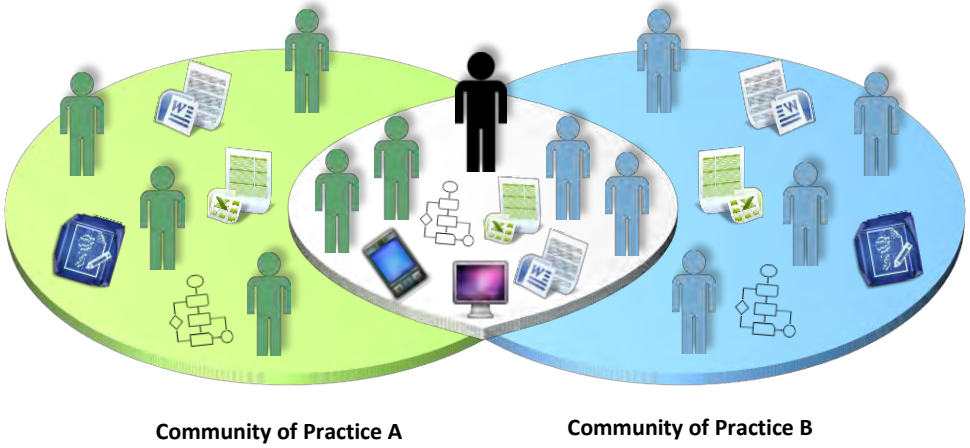
#### 5.3.2.3 The Use of Boundary Objects by Boundary Actors in Shared Spaces

Boundary actors (spanners and brokers) use boundary objects as mediating artefacts to resolve design problems and create design solutions within intersecting shared boundary spaces (Tharchen, Garud and Henn, 2020). To overcome differences in worldview perspectives and bridge fragmentations between heterogeneous communities, collaborating boundary actors can use and develop boundary objects to function as mediating artefacts that enable communication, knowledge sharing and negotiations for joint problem solving (Engeström,

Engeström and Kärkkäinen, 1995). In other words, boundary objects provide a means of collaborative problem solving by facilitating and supporting the "negotiating and combining [of] ingredients from different contexts to achieve hybrid solutions" (Engeström, Engeström and Kärkkäinen, 1995, p.319). By nature, boundary objects can be abstract and/or concrete (or along the continuum in-between), general or specific, conceptual or material, and conventional or user-adapted (Star and Griesemer, 1989; Worrall, 2014).

Boundary objects allow interdisciplinary collaborating team members to engage in knowledge sharing activities in shared spaces without demanding that they fully abandon their own practice community worldview perspectives, knowledge and practices (Winter and Butler, 2011). Boundary objects enable the *coordination* of heteropraxial activities by aligning and directing efforts towards achieving shared goals (Levina and Vaast, 2005), and help facilitate *cooperation* so that different perspectives, knowledge and practices shared across the intersecting community boundaries are acknowledged and respected (Worrall, 2014). Furthermore, boundary objects play a "critical role" in developing and maintaining *coherence* across intersecting communities of practice, which refers to the degree of consistency between different translations and communities of practice (Worrall, 2014). It is therefore important to manage and modify boundary objects over time (Star and Griesemer, 1989) and cater for residual categories (Star, 2010) to ensure that they remain relevant, useful and malleable in the face of knowledge, practice and technological advancements (Abraham, 2015) and the ever-changing and evolving nature of the interdisciplinary mHealth intervention app arena. *Convergence*, an information systems orientated expansion of the concept of coherence (Star, Bowker and Neumann, 2003), is also necessary to ensure consistency between the results of the collaborative translation process and the practice communities involved (Worrall, 2014).

Figure 5.7 provides an illustrative example of boundary objects "sit[ting] in the middle" of intersecting shared spaces (Star, 2010, p.608) where they use them as "a common point of reference" to engage in boundary crossing/spanning and problem solving activities within shared spaces (Abraham, 2015, p.67). The use of boundary objects supports coordination and cooperation within collaborating teams, and it is important that the coherence and convergence of these objects be flexibly managed over time.




| Icon Keys for Boundary Objects in Figure 5.7 | |
|---|---|
| | Excel documentation as a boundary object |
| | Documentation as a boundary object |
| | An application (app) prototype as a boundary object |
| | Computer-aided software as a boundary object |
| | A shared process map as a boundary object |
| | A shared technical drawing or sketch as a boundary object |

*Figure 5. 7: Boundary Actors Using Boundary Objects in Shared Spaces, Communities A and B [Source: Researcher's own construction, informed by Wenger (1998; 2000), Levina and Vaast (2005) and Rosenkranz, Vranešić and Holten, 2014)]*

#### 5.3.2.4 Types and Forms of Boundary Objects

A myriad of boundary objects – constituting various types, forms, roles and functions – can be employed and created by interdisciplinary collaborating team members at different stages of the mHealth design, development and evaluation process to mediate and bridge knowledge sharing and heteropraxial activities (Star and Griesemer, 1989; Bertelsen, 1998; Broberg, 2011). As illustrated in Figure 5.7, some simple boundary objects frequently utilised in multi- and interdisciplinary collaborative processes include excel documentation (Vashist, 2012; Kanwal, et al. 2019) and various types of documentation (Olsen, et al., 2012; Melville-Richards, 2015). More complex boundary objects include building and working prototypes (Henderson, 1991; 1998; Winkler, Huber and Dibbern, 2014; Heiss, 2020); computer assisted collaborative tools (Huvila, et al., 2016; Kanwal, et al., 2019); shared processes, frameworks and models (Melville-Richards, 2015; Huvila, et al., 2016); and technical drawings, sketches and mock-ups (Henderson, 1991; 1998; Broberg, 2011; Tharchen, Garud and Henn, 2020).

Depending on the contextual "design situation", work practices, informational needs and roles and intentions of the collaborating boundary actors at any given moment, the types and forms of boundary objects in use can vary significantly (Bertelsen, 1998, p.47; Nicolini, Mengis and Swan, 2012). In addition, boundary objects are not necessarily in active use at every stage of the interdisciplinary collaborative process. Instead, boundary objects shift by coming to the foreground when called into play by boundary actors in order to perform certain tasks, and fall back into the background when deemed unsuitable for a specific task at hand (Nicolini, Mengis and Swan, 2012). These shifts are dependent on the design problem, design context, design

issue, shared goals, and the boundary actors' knowledge, skills, competencies and motivating forces (Nicolini, Mengis and Swan, 2012). Furthermore, at the same time, one specific boundary object may produce multiple different affordances for different boundary actors, and may be useful in a range of diverse contexts, again depending on the context of use and the actors' competencies (Doolin and McLeod, 2012).

Albeit, regardless of the type or form of boundary object, Star (2010) emphasises that a critical characteristic of their value and pragmatic utility derives from actors deliberate acting toward and interaction with a given boundary object. In other words, a boundary object itself does not possess a "sense of prefabricated stuff or 'thing'-ness" (Star, 2010, p.603). Wenger (2010) mirrors this by underscoring that "artefacts without participation do not carry their own meaning, and [that] participation without artefacts is fleeting, unanchored and uncoordinated". This notion is further echoed by Nicolini, Mengis and Swan (2012), who explain that the pragmatic and material dimension of boundary objects derives from action (that is, they are enacted on by actors) and that the social and material dimensions are constitutively entangled in everyday life and practices. This essentially deems "sociomateriality and boundary objects [as] complementary perspectives" (Doolin and McLeod, 2012, p.571). In short, the social, pragmatic and material value derived from boundary objects in mediating mHealth intervention app project knowledge sharing and heteropraxial activities depends on the competencies of the boundary actors and the particulars of the context at any given moment in time, and that regardless of type or form, boundary objects do not possess value and utility within themselves.

Nevertheless, while boundary objects can constitute a multifarious range of types and forms, Star and Griesemer (1989) outlined four main types of boundary objects, namely: (1) *repositories*; (2) *ideal types*; (3) *coincidental boundaries*; and (4) *standardised forms*. Carlile (2002) redefined these four types as: (1) *repositories*; (2) *standardised forms*; (3) *objects and models*; and (4) *maps of boundaries*. Notably though, depending on the actors and context of use, the type categorisation of particular boundary objects is not always clear, and at times, they can simultaneously inhabit more than one category type (Carlile, 2002). Moreover, neither of these taxonomies are intended as exclusive or exhaustive (Star, 2010). Star (2010) explicitly refrains from making normative statements about what constitutes a boundary object and what type or form it should assume. Table 5.1 provides descriptions and examples of both Star and Griesemer's (1989) and Carlile's (2002) four-type boundary object taxonomies.

*Table 5. 1: Boundary Object Four-Type Taxonomies [Source: Researcher's own construction, informed by Michie, et al. (2011) and Hagger, Keatley and Chan (2014)]*

| Boundary Object Type | Type Description | Example(s) |
|---|---|---|
| ***Star and Griesemer's (1989) Four-Type Taxonomy*** | | |
| **Repositories** | Ordered 'piles' of objects indexed (or modularised) in a standardised fashion; organised by different unit of analyses. | Libraries; case study collections |
| **Ideal types** | Objects that enable symbolic communication and cooperation by providing an abstracted (and vague) description of details; offering a 'good enough roadmap' for all parties. | Diagrams |
| **Coincident boundaries** | Common objects that have the same boundaries but different internal contents. | Geographical maps |
| **Standardised forms** | Methods that support common communication across practice communities and grouping diverse content. | Standardised input information forms |
| ***Carlile's (2002) Four-Type Taxonomy*** | | |
| **Repositories** | Objects that provide a common point of reference of data, labels or measures, functioning as shared definitions and values for problem solving. They provide a means of representing knowledge. | A shared language (syntax) databases |
| **Standardised forms and methods** | Forms that provide a shared template or format for solving problems. Methods that provide a common process or shared methodology for solving problems. Both provide a means of representing and learning (or acquiring) knowledge. | Change forms; UCD methods; systems design methodologies. |
| **Objects and models** | Objects and models that offer simple or complex representations that can be observed and used across different practice settings. They provide a means of representing, learning (or acquiring) and transforming knowledge. | Drawings; sketches; mock-ups; prototypes |
| **Maps of boundaries** | Objects that help identify and illustrate dependencies and boundaries at a higher abstract, yet more systematic level, and that help support resource sharing and coordination. They provide a means of representing, learning (or acquiring) and transforming knowledge. | Gantt charts; work matrices; process maps. |

In light of Star's (2010) explicit refraining of normative statements, several auxiliary categorisations have been proposed in information systems literature over the years. Black and Andersen (2012) define *visual boundary objects*, which offer an ocular and observable means of representing and sharing design knowledge and practice. Levina and Vaast (2005) distinguish between *designated boundary objects* (artefacts that, due to their properties and design, are nominated as valuable for boundary spanning) and *boundary objects-in-use* (artefacts that, with or without designation, are valuable and useful in localised and joint community practices). From a sociotechnical perspective, Garrety and Badham (2001) define a *primary boundary object* as a particular technological artefact around which all design activity is focused, and a *secondary boundary object* as the subsidiary artefacts that support and facilitate the collective work around the primary object.

Inspired by the work of Wartofsky (1979), Nicolini, Mengis and Swan (2012) assume a sociotechnical and sociomaterial perspective in distinguishing between primary boundary objects, secondary boundary objects and tertiary boundary objects. *Primary boundary objects* are artefacts that directly motivate design activities, and are used during the collaborative production process (for example, a shared design solution and an app prototype). *Secondary boundary objects* are artefacts that facilitate and mediate, but do not motivate, collaboration (for example, interdisciplinary collaborative design, development and evaluation processes and methods). *Tertiary boundary objects* refer to the sociomaterial infrastructure and artefacts that indirectly support interdisciplinary team collaboration on the mHealth intervention app project (for example, buildings, rooms and computers). All three (primary, secondary and tertiary) types mediate different elements of the design process (Bertelsen, 1998), which demonstrates that the collaborative process and heteropraxial activities do "not depend only on one object, but on many" (Nicolini, Mengis and Swan, 2012, p.617).

In the context of design and information systems, *design artefacts* are boundary objects in that they mediate and tie together different interacting activity systems and praxes (Bertelsen, 1998; 2000). Bergman, Lyytinen and Mark (2007) define *design boundary objects* as:

> "*...any representational artefact that enables knowledge about a designed system [or device such as a mHealth intervention app], its design process, or its environment to be transferred between social worlds [communities of practice] and that simultaneously facilitates the alignment of stakeholder [interdisciplinary collaborating team member] interests populating the social worlds [communities of practice] by reducing design knowledge and practice gaps.*"

In mHealth (physical activity) behaviour change intervention app projects, design boundary objects are indispensable and are intricately interwoven in the design, development and evaluation process, and interdisciplinary collaborating teams can employ and create a diverse range of design artefacts in various forms to mediate and support their heteropraxial activities and heterogeneous knowledge sharing practices.

#### 5.3.2.5 The Core Criteria of Boundary Objects

Given the broad application of boundary object theory and the multifarious range of boundary objects identified across literature, it stands to reason that many have asked *"Couldn't anything be a boundary object?"* and *"What is NOT a boundary object?"* (Star, 2010, p.604). While

Star (2010, p.604) has emphasised her intention to "never [make] any attempt to adjudicate or prevent how anyone uses the [boundary object] concept" and expressly "refrain[s] from [making] normative statements about the true and proper meaning and use of boundary objects", she has outlined three core criteria. For an artefact to be recognised as a boundary object, it needs to meet all three criteria:

1. The interpretive flexibility of the objects
2. The structure of informatic and work process needs and arrangements of the objects
3. The dynamic between ill-structured and more tailored uses of the objects

***Criterion #1: Interpretive Flexibility***

Interpretive flexibility describes a boundary object that can serve as a sufficiently flexible and recognisable interface across multiple intersecting communities of practice by providing a "common point of reference" (Abraham, 2015, p.67) around which cooperation, communication and collaboration can be facilitated and mediated without significantly compromising any of the communities' different perspectives (Star and Griesemer, 1989; Star, 2010). A boundary object acts as a "means of translation" that enables shared understandings across heterogeneous practice community boundaries, but simultaneously accommodates different interpretations of meaning for boundary actors within their own localised practice communities (Star and Griesemer, 1989, p.393; Star, 2010). For example, Winkler, Huber and Dibbern (2014) and Heiss (2020) describe prototypes as affording different interpretations of meaning for different interdisciplinary collaborating actors. In interdisciplinary design teamwork, Tharchen, Gurad and Henn (2020, p.4) describes the term "design" as interpretively flexible in assuming "different meanings across disciplines" and having notably different meanings on global and local levels.

***Criterion #2: The Structure of Informatic and Work Process Needs and Arrangements***

The informatics and work process needs and arrangements essentially refer to the material and organisational structure of a boundary object (Star, 2010). Boundary objects need to account for and contain the minimum relevant information needs, work requirements and processual needs and arrangements of the various practice communities engaged in cooperation and collaboration praxes (Star and Griesemer, 1989; Star, 2010). In other words, a boundary object should aim to reflect as much necessary information as possible and should describe the relevant work arrangements and processes to inform practice and mobilise action (Bergman,

Lyytinen and Mark, 2007; Worrall, 2014). For example, Bergman, Lyytinen and Mark (2007, p.557) created a "proto-architecture design boundary object" to provide the minimum necessary design information for collaborating teams, which included requirement specifications, a diagram, description, cost estimates, and a roadmap guiding developmental progression. To support cooperative and collaborative design processes of end user tailoring, Eriksson (2008, p.185) proposed standardised usability and design patterns (in template form) to provide users and developers with "enough information" regarding the general, specific and architectural details of end user tailored software.

***Criterion #3: The Dynamics Between Ill-Structured and More Tailored Uses***

The dynamic between ill-structured and more tailored uses refers to a boundary object's ability to tack back-and-forth between providing a partial or temporary bridge that is "weakly structured" for general and joint (multi-community) use, but is also "strongly structured" for use within localised (individual-community) use (Star and Griesemer, 1989, p.393; Star, 2010). This dynamic is also described by the term "plasticity" (Star and Griesemer, 1989, p.397), referring to the degree to which a boundary object has the capacity to adapt between high levels of plasticity ("plastic") and low levels of plasticity ("robust") (Star and Griesemer, 1989, p.393). In its ill-structured form, a boundary object maintains a vague "common identity" to enable cross-community communication, cooperation and negotiation in collaborative interdisciplinary use, yet simultaneously holds sufficient structure that it can be tailored and fit for use by actors within their respective localised communities (Star, 2010; Kanwal, et al., 2019, p.101). Striking a balance in this dynamic is important (Dantew, 2013). This implies finding a balance in providing sufficient standards (to guide coordination, cooperation, communication and collaboration), while also providing flexibility as to not hinder localised use, nor impede adaptations, changes and innovations over time (which are imperative to creating innovative designs and progressing interdisciplinary fields) (Damtew, 2013). For example, Winkler, Huber and Dibbern (2014) distinguish between a building prototype (which provides a symbolic and conceptual representation of software requirements and design) and a working prototype (which provides a built and functioning piece of software). Eriksson (2008, p.185) describes his proposed standardised usability and design patterns as being "not too comprehensive" in providing end users and developers with an easy way to grasp adequate understanding "at a glance", but at the same time, providing sufficient detail for practicable implementation of the end user tailored software.

***Scale and Scope***

In addition to the three core criteria of boundary objects, Star (2010) further describes how a reference to "scale" and "scope" can help determine whether an artefact can be deemed a boundary object. In terms of scale and scope, a boundary object, for example, can range from a single word to a national flag, a film, or a music album (Star, 2010). Essentially, it boils down to the "circumstances" in which the artefact is being employed and utilised (Star, 2010, p.613). For instance, if an artefact (in conceptual or material form) is only providing interpretive flexibility and is not catering for informatics and work process needs and arrangements then it is not functioning as a boundary object. Whereas, if in "certain circumstances", an artefact that is not usually seen as a boundary object may be exhibiting all core criteria, regardless of its scale or scope, and thus would be deemed a boundary object.

#### 5.3.2.6 Other Characteristics of Boundary Objects

In addition to the three core criteria, by virtue of their nature, boundary objects tend to exhibit other characteristics (Nicolini, Mengis and Swan, 2012; Abraham, 2015; Huvila, et al., 2016). These other characteristics concern the (1) *abstractness/concreteness*; (2) *respecting practice community boundaries*; (3) *political and power dynamics and neutrality*; (4) *usefulness/utility, wholeness, accuracy and evolutionary remaking*; and the (5) *engineered artificiality* of boundary objects.

***Abstractness/Concreteness***

In reference back to Star and Griesemer's (1989, p.393) seminal definition of boundary objects, they describe them as being "abstract or concrete" (or simultaneously both). Winkler, Huber and Dibbern's (2014) building prototype would be an example of a more abstract boundary object, providing symbolic and visual representations in more theoretical and conceptual form, whereas their working prototype would be an example of a concrete boundary object, in which case actors can tangibly interactive with the real-world physical built prototype.

***Respecting Practice Community Boundaries***

While boundary objects provide boundary actors with a means of communicating, coordinating, cooperating and collaborating within intersecting shared boundary spaces, their use does not imply that the heterogeneous intersecting practice communities should dissolve their boundaries all together and fully merge or fuse (Akkerman and Bakker, 2011). Boundary

objects should respect practice communities in their own right, and should leverage their differences to generate new knowledge and develop innovative solutions (Wenger-Trayner, et al., 2017). Maintaining a "plurality of points of view" can be valuable and contribute to enriching the hybrid product solution (Trompette and Vinck, 2009, p.5). Project collaborations between diverse intersecting practice communities that are cross- or multidisciplinary in nature will have higher and stronger boundaries (Akkerman and Bakker, 2011). Whereas project collaborations that are inter- or transdisciplinary will have lower and weaker boundaries, and are generally representative of joint and new emerging fields (Levina and Vaast, 2005; Akkerman and Bakker, 2011). However, although new joint fields may emerge over time, the original practice communities are able to continue functioning and operating as independent communities in their own right. As a simple example, while the newly emerging mHealth behaviour change intervention app arena is representative of a growing interdisciplinary field (and possibly a transdisciplinary field in the future), the health behavioural sciences practice community and the information systems practice community both remain independent in their own right, in which case their community boundaries are being respected. Depending on their use in context, boundary objects need to respect heterogeneous practice community boundaries.

***Political and Power Dynamics and Neutrality***

Boundary objects need to cater for political and power dynamics, especially when it comes to negotiation and conflict resolution practices, and transforming and generating new knowledge and praxes (Carlile, 2002; 2004). Political and power dynamics are inherently embedded in boundary objects because they arise from the need to facilitate and mediate differences in perspectives, language, meanings and interests (Carlile, 2002; 2004). In addition, boundary objects can never be completely neutral because of the trade-offs that arise due to their use in joint problem solving, decision making and design transformation practices (Carlile, 2006; Stoytcheva, 2015; Huvila, et al., 2016). However, for boundary objects to provide a sufficiently effective and efficient means of collaborative teamwork, they should aspire to maintain as much objectivity and neutrality as possible in representing and including all diverse intersecting practice communities (Stoytcheva, 2015; Huvila, et al., 2016).

***Usefulness/Utility, Wholeness, Accuracy and Evolutionary Remaking***

"No boundary object can be universally useful" (Stoytcheva, 2015, p.5) and no boundary object should strive to offer collaborating boundary actors a "catch-all" perfect or absolute solution

to the extent "where it tries to explain everything" (Nicolini, Mengis and Swan, 2012, p.614). It is not possible that a boundary object offers a "magic bullet" solution because its value derives from its use by actors in action and context (Carlile, 2004, p.565; Star, 2010). In the real world, the usefulness and utility of boundary objects relies so heavily on contextual and situational factors and actors' interactions (with objects and each other), that boundary objects can inadvertently produce paradoxical or possible adverse outcomes (Carlile, 2002; 2006). For instance, in one setting, a boundary object may provide substantial value, whereas in another setting it may become a "boundary roadblock" (Carlile, 2002, p.451). The usefulness and utility of a boundary object derives from collaborating actors' sociomaterial engagements, active sensemaking and reflexive practices, and does not derive from the object possessing an inherent property or capability (Fox, 2011).

Star (2010) also emphasises that boundary objects need not be wholly or meticulously accurate to be useful, but instead should aim to serve as a basis for fostering knowledge sharing, communication, negotiation and collaboration between relevant practice communities. For example, a diagram (as an "ideal" boundary object type, Table 5.1) should provide collaborating actors with the "lowest common denominator" structure to satisfy the minimum demands of each community (Star and Griesemer, 1989, p.404), and should aim to provide a "good enough roadmap" rather than a whole intricately detailed perfect solution (Star and Griesemer, 1989, p.410). Furthermore, depending on the context and actors, boundary objects are not necessarily accurate common points of reference, and considering changes and advancements over time, there is "no guarantee" that a boundary object will be useful or accurate, and at times, may also be fallible (Stoytcheva, 2015, p.5; Huvila, et al., 2016). Boundary objects need to provide sufficient structure, stability and standardisation; however, in the face of changes and advancements over time, they should also remain flexible and malleable over time, catering for "residual categories" and modifications (Star, 2010, p.614), and therefore should be in a "constant process of (re)making" (Huvila, et al., 2016, p.1812).

***Engineering Artificiality***

In a progressive field like information systems, Star (2010, p.305) addresses the question *"Would it be possible to design boundary objects?"*. This would suggest engineering boundary objects motivated by the principal goal of "creating a better society" (Bowker and Star, 1999, p.305), which parallels the motivations behind the emerging mHealth behaviour change intervention app arena and the pragmatic view of ongoing cycles of practicing, experiencing,

learning and reflecting as a pathway to "progress [towards] building a better society" (McGill, 1939, p.297). While some boundary objects come into being organically, it is possible to design and author theoretical, conceptual and pragmatic artefacts with the explicit intention that they serve as boundary objects for bringing knowledge and praxis gaps between heterogeneous intersecting practice communities (Bowker and Star, 1999; Star, 2010; Huvila, et al., 2016). Engineering boundary objects, however, should be done with caution. Effort should be made to meet the three core criteria, meet the informatic and work process needs and arrangements of all relevant communities, ensure balance between standardisation and flexibility, and refrain from ignoring or imposing membership categories on actors (Bowker and Star, 1999).

An example of an engineered boundary object is Eriksson's (2008, p. p.198) participatory and cooperative design process, which comprises "tools" such as a categorisation tool, matrix, usability patterns and design patterns, and which he justifies as an "artificial" (engineered) boundary object by meeting the three core criteria. Rosenkranz, Vranešić and Holten's (2014, p.315) also propose an engineered boundary object in the form of a framework by reviewing literature and "develop[ing] a conceptual framework a priori" before testing it in a case study, after which the findings informed the refined framework contribution. Using DSR, Bittner and Leimeister (2014, p.110, p.108) engineered a collaborative process design approach in the form of a "facilitation process model" to support heterogeneous (multidisciplinary) work groups in creating shared understanding, and highlight the importance of grounding collaborative design activities in "good" rigorous theory to help guide heteropraxial design decisions and design solution practices. In a nutshell, engineering boundary objects can be progressive and useful for newly emerging joint arenas such as the mHealth behaviour change intervention app field. Engineered boundary objects can also be particularly valuable when aiming to ground a DSR artefact contribution in good evidence-based theory and literature findings, and when intentionally aiming to bridge the knowledge and practice gaps in shared interdisciplinary boundary spaces (such is the case with this research project's proposed framework artefact).

#### 5.3.2.7 Criticisms and Limitations of Boundary Object Theory

Boundary object theory has received criticism mostly from its "vague and fuzzy" definition (Feldhoff, et al., 2019, p.4) and its "over-zealous" use (Melville-Richards, 2015, p.76). This has led some to suggest that it has, at times, been applied in "an anecdotal manner to refer to any artefact which is involved in coordination between actors or which is at the boundary of two worlds" (Trompette and Vinck, 2009, p.8). It has also been expressed that the boundary

object concept "is not incorrect [but] incomplete" (Lee, 2007, p.313). Proposals and arguments have been made for objects and artefacts that are similar to, but supposedly distinguishable from, boundary objects.

Lee (2007, p.318, p.333), for instance, proposes the notion of "boundary negotiation artefacts", which as she sees it, "do not fit the definition of boundary objects" because they push and challenge boundaries rather than "merely sailing across" them. Hendersen (1991, p.480; 1999, p.140) proposed "conscription devices" which refer to visually-orientated design inscription tools, such as documentation, sketches, drawings, models, prototypes and computer-aided design software. While boundary objects and conscription devices share many characteristics, there is no clear-cut distinction between them, with some arguing that conscription devices are a type of boundary object (Pfister and Eppler, 2012) while others argue that conscription devices are "not boundary objects at all" (Lee, 2007, p.312). A similar issue is identifiable with Subrahmanian, et al.'s (2003, p.187) proposed concept of "prototypes", which they distinguish from boundary objects. Subrahmanian, et al. (2003, p.187) explain that prototypes not only serve as a "static means for translation", but that they can also undergo dynamic iterative changes as their representational status is repeatedly broken down and rebuilt to establish a shared understanding between participants during the collaborative design process. Many researchers, however, identify prototypes as a type and form of boundary object (Carlile, 2002; Levina and Vaast, 2005; Khaled and Vasalou, 2014; Winkler, Huber and Dibbern, 2014; Kanwal, et al., 2019; Rousseau, et al., 2019; Heiss, 2020; Tharchen, Garud and Henn, 2020), which again illustrates ambiguity in the lack of clear-cut distinctions between such proposed concepts. Another example is Boujut and Blanco's (2003, p.205) proposed concept of "intermediary objects", which they describe to "act as boundary objects", whereas Lee (2007, p.312) argues that intermediary objects are "something other than boundary objects" but fails to elaborate on or justify this claim.

Overall, while these criticisms and ambiguities are reasonable, the broad application and use of boundary object theory has led it to "enjoy[] a vigorous academic career", particularly in the social science, computer science, management, engineering, design and information systems disciplines (Trompette and Vinck, 2009, p.8), deeming it a valid and credible theory.

### 5.3.3 Knowledge Boundary Theory

#### 5.3.3.1 The Knowledge Boundary Framework

Improving the interdisciplinary collaborative design, development and evaluation process and the product output of mHealth (physical activity) behaviour change intervention app projects requires that heterogeneous knowledge grounded within several relevant practice communities be shared and integrated between team members. It is within the shared boundary space of intersecting communities that design knowledge can be transformed to create better and more innovative mHealth intervention app design solutions. Sharing knowledge across heterogeneous practice communities is generally challenging because collaborating team members contribute expertise that is informed by their own community's "unique terminology, tools, practices, or incentives", which in turn establishes "knowledge boundaries" between the intersecting communities of practice (Carlile and Rebentisch, 2003, p.1182).

*Knowledge*, from a pragmatic perspective, can be described as "localised, embedded and invested in practice" (Carlile, 2002, p.442). Since each collaborating team member holds their own community-specific tacit "knowledge in practice", communicating and sharing knowledge with team members from other communities can be particularly challenging, especially considering that their heterogeneous knowledge is informed by their different worldview perspectives, philosophies, vocabularies, norms, processes and practices (Carlile, 2002, p.442). Ironically, knowledge becomes both a source and a barrier to interdisciplinary communication and collaboration, and paradoxically, knowledge boundaries become both a necessity (in that they respect and differentiate diverse knowledge contributions) and a critical challenge (in that they need to be addressed and overcome) (Carlile, 2002; 2004).

To address the challenges faced by knowledge boundaries, Carlile (2004) proposed an integrative framework for managing knowledge across community of practice boundaries. Carlile's (2004) conceptual model of knowledge boundary theory – provided in Figure 5.8 – depicts an inverted equilibrium triangle for illustrating the three progressively complex knowledge boundaries (syntactic, semantic and pragmatic) and the three progressively complex knowledge processes (transfer, translation and transformation). Boundary objects play an integral role in establishing an "infrastructure" or "process" where knowledge can be "represented, learned and transformed" (Carlile, 2002, p.454). While Star and Griesemer's (1989; Star, 2010, p.605) boundary object theory generally supports "the mediation of knowledge" between practice communities on levels of information processing (transfer) and

interpretation of meaning (translation), Carlile's (2002; 2004) framework adds a third political level that aims to address conflicting interests/goals and generate new innovative knowledge (transformation). In other words, boundary object theory fails to adequately address the role of boundary objects in negotiating and resolving political and power related issues, which is necessary for transforming knowledge in the emerging interdisciplinary mHealth behaviour change intervention app arena.

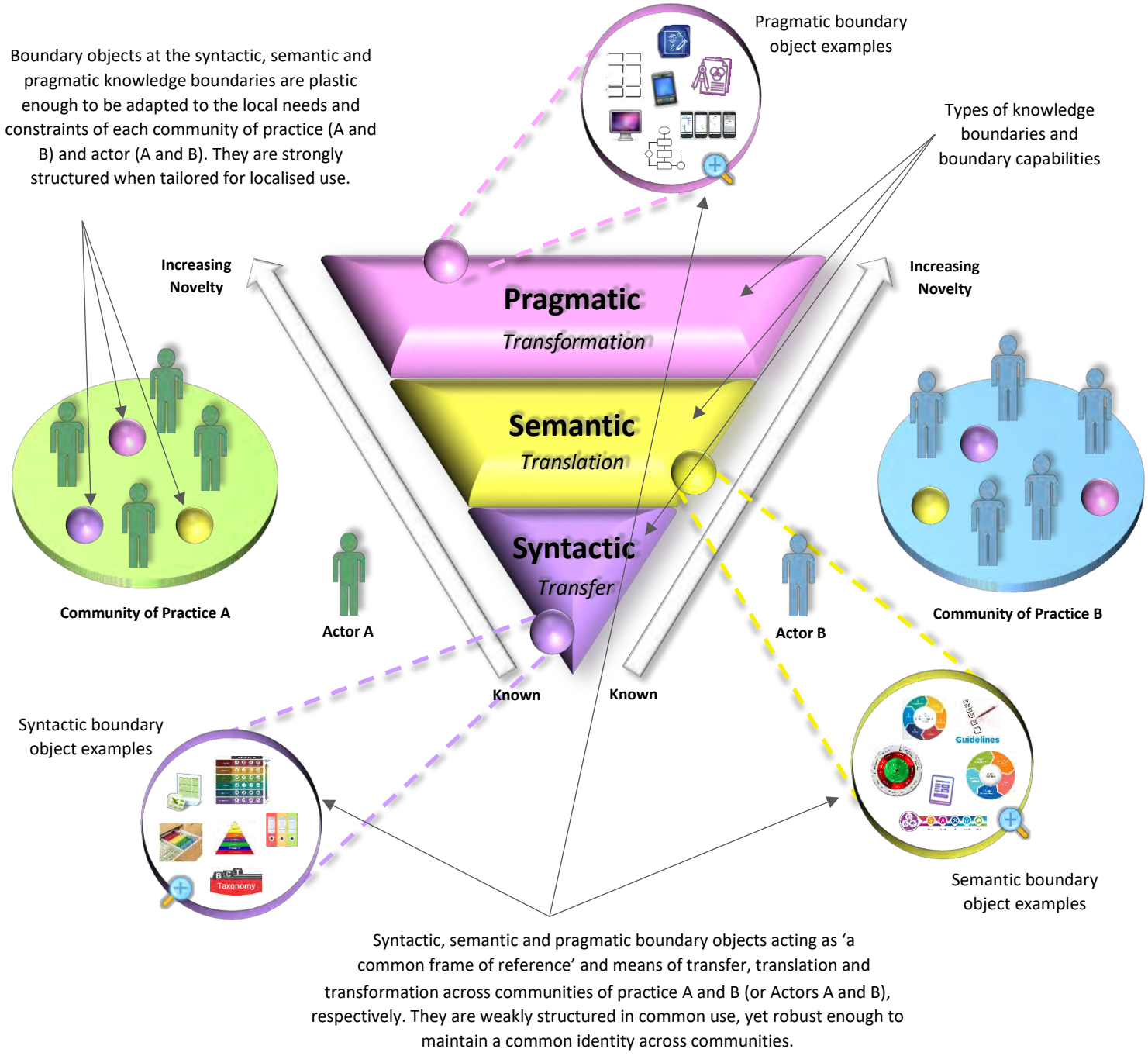



*Figure 5. 8: Integrative Knowledge Management Framework, with Boundary Object Examples [Researcher's own construction, informed by Carlile (2002; 2004; 2006), Eriksson (2008), Michie, et al. (2011; 2013), Rosenkranz, Vranešić and Holten (2014), Winkler, Huber and Dibbern (2014) and Kanwal, et al. (2019)]*

| Icon Keys for Boundary Objects in Figure 5.8 | | | | | |
|---|---|---|---|---|---|
|  | Magnifying glass zoomed into the knowledge boundary |  | A shared process as a boundary object |  | Screen mock-ups as a boundary object |
|   | CALO-RE taxonomy and Behaviour Change Technique Taxonomy v1 as boundary objects |  | The Behaviour Change Wheel as a boundary object |  | A shared process map as a boundary object |
|  | A filing system as a boundary object |  | A shared form, template or pattern as a boundary object |  | An application (app) prototype as a shared boundary object |
|  | A classification, indexed or ordered system as a boundary object |  | A shared methodology as a boundary object |  | A shared storyboard as a boundary object |
|  | A categorisation tool as a boundary object |  | A shared method as a boundary object |  | A shared technical diagram or blueprint as a boundary object |
|  | A taxonomy as a boundary object |   | Standardised guidelines as a boundary object |  | A shared technical drawing or sketch as a boundary object |
|  | Excel documentation as a boundary object |  | Computer-aided software as a boundary object | | |

Carlile's (2004) integrative knowledge boundary framework builds on Star and Griesemer's (1989) boundary object theory and integrates theory from linguistics (Cruse, 2000) and mathematical information and communication (Shannon and Weaver, 1949). Although originally proposed within management and organisational sciences and product development, knowledge boundary theory has subsequently been applied to a broad range of disciplines and contexts. From a health perspective, some contextual applications include health sciences (Edenius, Keller and Lindblad, 2010; Melville-Richards, 2015; French, 2016) and public health and wellbeing promotion (Wall, 2017). From a technological perspective, applications include information systems and systems design and development processes (Strašunskas, 2006; Rosenkranz, Vranešić and Holten, 2014; Winkler, Huber and Dibbern, 2014), and gamification (Hannula, 2014). In terms of design, contextual applications include participatory design (Broberg, 2011) and co-design processes (Islind, et al., 2019). At the intersection of these fields, knowledge boundary theory has also been applied to digital health contexts (Damtew, 2013; Islind, et al., 2019).

#### 5.3.3.2 Relational Knowledge Properties: Differences, Dependencies and Novelties

Three knowledge properties describe the relative complexities, challenges and consequences that arise at each of the three (syntactic, semantic and pragmatic) knowledge boundaries, namely (1) *difference*, (2) *dependence* and (3) *novelty* (Figure 5.8). An understanding of these three knowledge properties gives insight into how knowledge can be better managed and integrated across the boundaries of collaborating practice communities.

***Difference***

A *difference* in knowledge describes either a difference in the amount of knowledge accumulated (for example, distinguishing between a novice and expert health psychologist), or a difference in the type of community-specific (specialised) knowledge accumulated (for example, distinguishing between health psychology, user experience design, and mobile app development) (Carlile, 2002; 2004). Differences in the amount and type of knowledge are necessary and imperative for addressing mHealth behaviour change intervention app design issues, and creating innovative design solutions. Knowledge differences become apparent through the different worldview perspectives, vocabularies, interpretations of meaning, degrees of experience, tools, methods, approaches, interests, goals and motivations unique to each community of practice (Carlile, 2002; 2004). A key challenge is that not all differences are known up front (Carlile, 2004); they tend to become apparent over time as the team progresses through the interdisciplinary collaborative project process.

***Dependency***

A dependency in knowledge refers to the interrelationships and consequential links between the activities and goals of boundary actors who are dependent on one another (Carlile, 2004). In mHealth intervention app projects, collaborating team members need to consider how their design knowledge, activities, actions, methods and goals will affect and have an impact on others. Dependency and difference are not mutually exclusive for "without dependence, difference is of no consequence" (Carlile, 2004, p.556). Essentially, the interdisciplinary collaborating team members rely on each other's' contributions throughout the project process, and their interdependencies are engrained in their working towards attaining their shared goal and producing the final mHealth app product. The main challenge is that each contributing practice community is committed to and invested in their own knowledge, practices and interests, yet these things are not mutually exclusive from or inconsequential to others within the intersecting shared boundary space (Carlile, 2002; 2004). Another challenge is that not sources of dependency are known up front (Carlile, 2004); they generally emerge and become identifiable as the team progresses through the interdisciplinary collaborative process.

***Novelty***

Novelty arises when new circumstances are introduced at a given boundary (Carlile, 2004). New circumstances can be in the form of new actors, technologies, processes, methods,

theories, informatic and work process needs and requirements, product requirements, or the creation of new joint (transformed) knowledge; all of which indirectly and directly affect design innovation (Carlile and Lakhani, 2011). From a relational perspective, the introduction of novelty creates challenges for knowledge sharing since collaborating team members no longer possess the capacity to adequately represent and communicate their differences and dependencies, which hinders their ability to effective share knowledge at the boundary (Carlile, 2004). This has consequences on the coherency of knowledge sharing and boundary objects (a concept described in Subsection 5.3.2.3). Novelty also arises in the form of new knowledge; developing through knowledge integration or knowledge generation. When interdisciplinary teams engage in collaborative negotiation, conflict resolution, problem solving, idea generation and solution forming practices they are essentially creating novelties and new knowledge. New knowledge is also created when teams devise new approaches, processes, methods and models for interdisciplinary collaborative teamwork and heteropraxial activities. Novelty can be challenging in that often requires a significant amount of effort to address (if presented as a new circumstance) and effort to develop (if integrating and generating new knowledge).

#### 5.3.3.3 Syntactic, Semantic and Pragmatic Knowledge Boundaries

The three knowledge properties move up and down the inverted triangle in Figure 5.8 as they increase and decrease along the knowledge boundaries (Carlile, 2004). As illustrated in Figure 5.8, there are three progressively complex knowledge boundaries, namely the (1) *syntactic*, (2) *semantic*, and (3) *pragmatic* boundaries. These boundaries are associated with three progressively complex knowledge processes, namely the (1) *transfer*, (2) *translation*, and (3) *transformation* processes, respectively (Carlile, 2002; 2004). There are a different set of circumstances, challenges and suggested solutions to overcome each knowledge boundary (Carlile, 2004). In mHealth intervention app projects, depending on the circumstances and challenges present at a given knowledge boundary, different boundary objects can be employed and created to overcome the differences, dependencies and novelties in knowledge betwixt the heterogeneous collaborating team members. Boundary objects help interdisciplinary teams establish shared languages for representing knowledge, provide a concrete method for learning about differences and dependencies, and facilitate knowledge transformation and generation.

***The Syntactic Knowledge Boundary***

The *syntactic knowledge boundary* – the bottom purple layer in Figure 5.8 – involves the *transfer* of knowledge across community boundaries in circumstances where differences and

dependencies are relatively known (Carlile, 2004). The main challenge present at the syntactic boundary concerns *differences in language* (vocabulary and terminology) between the heterogeneous collaborating actors (Carlile, 2002; 2004). Developing a *common language*, which can be achieved by creating a common lexicon (or shared syntax) that sufficiently specifies language differences and dependencies, can help facilitate the transfer of information and knowledge across the syntactic boundary (Carlile, 2004).

As illustrated by the zoomed-in purple circle in Figure 5.8, examples of boundary objects on the syntactic level include taxonomies, repositories, indexed or ordered objects, libraries, classification and filing systems, and glossaries (Star and Griesemer, 1989; Carlile, 2002; 2004; 2006). Examples from relevant literature include shared matrix tools (Erikkson, 2008), shared repositories, shared requirements definitions and shared excel documentation (Rosenkranz, Vranešić and Holten, 2014), and the CALO-RE and v1 behaviour change technique (BCT) taxonomies, which provide a "consensually agreed hierarchically structured" (Michie, et al., 2013, p.81) "common language" (Michie, et al., 2011, p.1484). These objects align with the "repositories" boundary object type in Table 5.1. Essentially, syntactic boundary objects provide interdisciplinary collaborating team members with a means of "representing" knowledge (Carlile, 2002, p.453). Important to note is that given the "young" (Mummah, et al., 2016, p.1) nature of the emerging mHealth behaviour change intervention app arena, the breadth and depth of language differences and dependencies across all intersecting practice communities is not yet fully known or specified. In such circumstances, Carlile (2004, p.560) suggests using objects that can provide a "sufficient" means for transferring knowledge and information processing; syntactic boundary objects need not be perfect or all-inclusive of language differences to be useful.

***The Semantic Knowledge Boundary***

The *semantic knowledge boundary* – the middle yellow layer in Figure 5.8 – involves the *translation* of knowledge across community boundaries where an increase in novelties (up along the inverted triangle) leads to differences and dependencies that are unclear, ambiguous and unknown, resulting in a loss of shared interpretation of meaning (Carlile, 2002; 2004). The main challenge present at the semantic boundary concerns *differences in interpretation and meaning* betwixt heterogeneous collaborating actors (Carlile, 2004). Developing *common meanings* (shared meanings) or mechanisms that reconcile discrepancies in meaning can help facilitate the translation of knowledge across the semantic boundary (Carlile, 2004).

Differences in interpretations of meaning are usually a result of differences in worldview perspectives, "thought worlds", terminological usage, and practice specialisation (Dougherty, 1992, p.179; Carlile, 2002).

As illustrated by the zoomed-in yellow circle in Figure 5.8, examples of boundary objects on the semantic level include shared methodologies, shared processes, standardised and shared forms, shared problem-solving templates, shared methods, and standards for reporting (Star and Griesemer, 1989; Carlile, 2002; 2004; 2006). Examples from relevant literature include collaborative and cooperative design processes and shared patterns (Eriksson, 2008), shared guidelines (Melville-Richards, 2015), standardised visual design guidelines (Abraham, 2015), co-design processes (Islind, et al., 2019), the CONSORT-EHEALTH standards and guidelines (Eysenbach, 2011), and the behaviour change wheel (BCW) which provides a "systematic method" (Michie, et al., 2013, p.43). These objects align with the "standardised forms and methods" boundary object type in Table 5.1. Essentially, semantic boundary objects provide interdisciplinary collaborating team members with a means of "representing [and] learning about" differences and dependencies in knowledge (Carlile, 2002, p.453). Boundary brokers (knowledge brokers) often act as translators who facilitate the knowledge translation process across the semantic boundary and help the interdisciplinary team develop common meanings (Carlile, 2004; Rosenkranz, Vranešić and Holten, 2014). Akin to the syntactic knowledge boundary, it is not possible that all interpretation of meaning differences are known to date; however, a sufficient grasp of these differences is useful for translating knowledge; semantic boundary objects need not be perfect or all-inclusive to be useful.

***The Pragmatic Knowledge Boundary***

The *pragmatic knowledge boundary* – the top pink layer in Figure 5.8 – involves the *transformation* of knowledge across community boundaries where further increases in novelties (up along the inverted triangle) requires "negotiating interests and making trade-offs between actors" (Carlile, 2002; 2004, p.559). The main challenges present at the pragmatic boundary are political and power related, and concern *differences in interests* betwixt heterogeneous collaborating actors (Carlile, 2004). Developing *common interests* (shared interests and shared goals) can help facilitate the transformation of knowledge across the pragmatic boundary (Carlile, 2004). Differences in interests are usually a result of differences in worldview perspectives, "thought worlds", values and motivations (Carlile, 2002).

Of the three knowledge boundaries, the pragmatic level is the most challenging and requires the most effort to overcome since actors are generally strongly committed to and invested in their values, motives, knowledge, practices, methods, standards and procedures as "hard-won outcome[s]" (Carlile, 2002, p.445). Negotiating and developing common interests and generating new knowledge with actors from other communities requires them to partially forgo and abandon their own invested interests and knowledge, which is perceived to be "at stake" and is believed to generate "costs" and "negative consequences" (Carlile, 2002, p.445). Actors perceive their knowledge to be "at stake" because of the power, status, remuneration and qualifications associated with their expertise and skills, which generally cultivates reluctance and resistance to change (Carlile, 2002; 2004). While transforming and generating new knowledge requires actors to develop and advance their skill sets, they often perceive pragmatic negotiations and trade-offs as a process of deskilling, and hence usually view their knowledge, expertise and skills as something that is threatened and potentially sabotaged (Carlile, 2004).

As illustrated by the zoomed-in pink circle in Figure 5.8, examples of boundary objects on the pragmatic level include objects and models that provide heterogeneous collaborating team members with a "good enough roadmap" (Star and Griesemer, 1989, p.410) so that knowledge can be "jointly transformed", such as prototypes, diagrams, drawings, maps and technical models (Carlile, 2002; 2004, p.560). Prototypes specifically, according to Carlile (2004, p.559), "have prove[n] [to be] effective in providing concrete means of representing different functional interests and facilitating [the] negotiation and transformation [of knowledge] in product development settings". Examples from relevant literature include software and app prototypes, drawings, sketches, storyboards, mock-ups, scenarios, models, workflow matrices and charts, technical and process maps (Bertelsen, 2000; Bergman, Lyytinen and Mark, 2007; Winkler, Huber and Dibbern, 2014; Heiss, 2020) and interdisciplinary collaborative frameworks and processes (Feldhoff, et al., 2019; Caccamo, 2020). These objects align with the "objects and models" and the "maps of boundaries" boundary object types in Table 5.1.

Pragmatic boundary objects essentially provide interdisciplinary collaborating team members with a means of "representing, learning and transforming" knowledge (Carlile, 2002, p.453). In comparison to syntactic and semantic objects, pragmatic objects are generally more material and concrete, providing collaborating actors with a more tangible, engaged and interactive means of perspective-making and perspective-taking, so that they can explicitly represent, demonstrate, address and resolve differences in interests. Boundary brokers (knowledge

brokers) often serve as mediators during negotiation, conflict resolution and knowledge generation activities at the pragmatic boundary and help the interdisciplinary team develop common interests and goals (Carlile, 2004; Rosenkranz, Vranešić and Holten, 2014). Akin to the syntactic and semantic knowledge boundary, it is not possible that all differences of interest are known when a mHealth intervention app project commences; however, it is necessary that pragmatic boundary objects be sufficiently useful for addressing and resolving political and power conflicts and differing interests/goals (Carlile, 2004; Akkerman and Bakker, 2011).

#### 5.3.3.4 Additional Knowledge Boundary Related Considerations

Important to note is that the delineations between the syntactic, semantic and pragmatic knowledge boundaries are not always clear or easily discernible (Carlile, 2004). In addition, the three knowledge boundaries are not necessary mutually exclusive since they build upon each other. In other words, as differences, dependencies and novelties increase upwards along the progressively complex knowledge boundaries (Figure 5.8), the capabilities and processes of the more complex boundaries requires the capabilities and processes of the boundaries below it. For example, developing common interests, transforming knowledge and addressing political and power issues at the pragmatic boundary requires interdisciplinary collaborating team members to have first established an adequate common language and common meanings. Furthermore, although the boundary object examples provided in Figure 5.8 seem to be demarcated as useful for addressing challenges at specific knowledge boundaries, it often happens that specific boundary objects are able to facilitate and mediate challenges on more than one level. For example, a prototype, which is primarily viewed as a pragmatic knowledge artefact for addressing different interests (Carlile, 2004), can also be used by heterogeneous collaborating actors to represent and learn about different interpretations of meaning (which would be at the semantic level). Therefore, many objects, depending on the competencies and skills of the actors using them, can be useful at more than one particular knowledge boundary (Carlile, 2004). Moreover, while some interdisciplinary teams may find certain boundary objects to be effective at addressing certain knowledge related challenges, other teams may find the same object to be ineffective. Again, this depends on the actors' knowledge, skills and competencies, and again reinforces the notion that objects do not inherently possess a "sense of prefabricated stuff or 'thing'-ness", but rather that their utility derives from actors deliberate acting toward and interaction with a given boundary object (Star, 2010, p.603).

#### 5.3.3.5 Criticisms and Limitations of Knowledge Boundary Theory

Knowledge boundary theory has generally been criticised for viewing knowledge from a pragmatic and practice perspective. As stated when first introducing Carlile's (2004) integrative knowledge framework (Subsection 5.3.3.1), knowledge is viewed as being "localised, embedded and invested in practice" (Carlile, 2002, p.442), which means that knowledge is perceived to be a part of action and inseparable from and intrinsically bound to practice. Several works have highlighted this criticism and have proposed alternative perspectives to knowledge integration and generation. Some have proposed adopting a communications perspective, which conceptualises knowledge as a dynamic and context-dependent process that emphasises the dialogue, social interactions and interpersonal communications around sharing, integrating and creating knowledge (Enberg, 2007; Mengis, 2007; Wahlstedt, 2014; Kosonen, 2015). Others have proposed a cognitive perspective (Robert, Dennis and Ahuja, 2008); a cognitive, sociocultural and constructivist perspective (Chiu and Linn, 2011); an emotional, attitudinal and behavioural perspective (Sankowska and Söderlund, 2015), and a productivity and technological perspective (Dibiaggio, 2007).

While Carlile's (2002; 2004) pragmatic perspective recognises knowledge integration as an emerging process resulting from collaborative interactions and practices between heterogeneous parties, Enberg (2007, p.5) argues that it fails to consider "the way in which the [knowledge integration] process is structured". From Enberg's (2007) point of view, understanding the knowledge integration process also requires investigation into how people hold knowledge, how the same knowledge can be held in different ways, how actors convert and share knowledge (from tacit to explicit form), and how final output products emerge as a result of the knowledge integration process. The process of how actors bring "deep knowledge" to light and how actors can represent it in ways that are comprehendible and understandable for people from different disciplinary backgrounds is another challenge Carlile's (2004) theory fails to consider (Majchrzak, More and Faraj, 2012, p.952).

On another note, Broniatowski and Magee (2018) argue that Carlile's (2004, p.565) view of experts as being unwilling to learn from one another because of their deep assumptions rooted in their past experience, and his view of experts as struggling and resistant to dealing with novelties and falling into "competency trap[s]", is not necessarily correct. Broniatowski and Magee (2018, p.340) argue that experts are more capable of "operating successfully" and are more willing to spend their time assessing their own ability to contribute when introduced to

novel situations than Carlile believes, and they argue that experts are more willing to collaborate and make decisions based on "shared common (non-expert) knowledge" than Carlile credits. Broniatowski and Magee (2018, p.340) further argue that expert collaboration in novel situations is likely to lead to the "collapse" of knowledge boundaries through the development, sharing and generation of new common knowledge.

Overall, while these criticisms have merit, the broad application and use of Carlile's (2004) knowledge boundary theory to various disciplines, contexts and problems demonstrates its value as a theoretical lens for addressing knowledge challenges. Carlile's (2004) theory is also appropriate considering that it assumes a pragmatic perspective, which aligns with the philosophical worldview perspective of this research project (Figure 5.1), and it is informed by and builds on Star and Griesemer's (1989) boundary object theory and is harmonious with community of practice theory, evidencing a congruent alignment of the three theories.

## 5.4 The Boundary Object View as an Appropriate Theoretical Framework

The adoption and application of a theoretical framework is "one of the most important aspects in the research process" (Grant and Osanloo, 2014, p.12) and is a "mandatory ingredient" in producing quality doctoral research (Adom, Hussein and Agyem, 2018, p.438). A theoretical framework provides "the spectacles" and "frame of reference" with which a researcher chooses to view and interpret phenomena (Imenda, 2014, p.185). In addition, a theoretical framework provides a deductive "lens" and "analytic approach" for how the researcher views and thinks when investigating a problem, analysing data and developing solutions that will contribute to knowledge (Grant and Osanloo, 2014, p.24; Imenda, 2014; Collins and Stockton, 2018, p.2). Analogically speaking, a researcher "borrow[s]" the blueprints of "someone else's theory… to build their own home"; that is, the theoretical framework provides a solid, credible and reliable foundation for a researcher to build their own research (Grant and Osanloo, 2014, p.16).

The tactful selection of an appropriate theoretical framework "deepen[s] the essence" of a research study, and evidences that a study is rooted in established and credible theory rather than being based on personal bias and instincts (Adom, Hussein and Agyem, 2018, p.438). The key concepts of a theoretical framework can be drawn from one or more theories and are selected with consideration for the research discipline, problem, context and tentative suggested solution/knowledge contribution (Grant and Osanloo, 2014; Collins and Stockton,

2018). Selecting and amalgamating more than one theory into a tailored theoretical framework can provide a novel approach and perspective to addressing a defined problem, as in the case of this research project. According to Walsham (2006), the chosen theory or theories can be diverse, albeit need to be harmonious, and their application can be relatively loose or tight depending on their intended purpose. Walsham (2006, p.324-325) also contends that the selected theory is "essentially subjective" in that a researcher will "choose theories which *they* feel are insightful to *them*" and because the particular theory(ies) "spoke to them". While the subjective selection of a chosen theory (or theories) does not discredit its validity, credibility or reliability a suitable lens/frame of reference, it is important that the researcher justifies their choice as relevant and appropriate to the research topic, problem and objective, and that they remain critical and cognisant of the theory(ies) criticisms and limitations (Walsham, 2006). These practices are demonstrated by the researcher's continuous provision of justifications, evidence, critical thought and referenced examples throughout this chapter's discussions, particularly in Subsections 5.3.1, 5.3.2 and 5.3.3.

On a philosophical level, the pragmatic, sociomaterial, design and artefact orientated worldview perspectives of the three selected theories are harmonious and congruent with each other, and with the paradigm and DSR methodology applied in this research project (Figure 5.1). This philosophical, paradigmatic, methodological and theoretical framework compatibility has also been demonstrated in several other information systems research studies and doctoral dissertations that have applied either one or more of the community of practice, boundary object and/or knowledge boundary theories together with a DSR methodology, to produce a novel artefact contribution. Examples of such information systems research and doctoral studies include Hölttä (2013), Abraham (2015), Uppström (2017), Hazbi (2018), Park (2018), Francisco and da Costa Zanela Klein (2020), McCarthy, et al. (2020).

## 5.5 Conclusion

This chapter lays the theoretical foundation for answering the third research sub-question by introducing and detailing the tri-composite theoretical framework, concisely referred to as the *"boundary object view"*, which is used to frame the tentative suggested design artefact solution (Figure 5.1). First off, a succinct moulding of the thesis problem and justification for the significance and need for new multi- and interdisciplinary approaches to guide and support the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps was provided. The tri-composite theoretical framework, comprising

three credible and reliable theories, namely community of practice theory, boundary object theory and knowledge boundary theory, was then introduced as a proposed novel pragmatic, sociomaterial, design and artefact orientated approach to addressing the defined problem.

The following section then introduced and discussed each of the three theories, detailing each of their core constructs, providing justifications for their suitability as kernel theories and lenses for addressing the problem, and giving examples of their applications in multi/interdisciplinary, digital health and design contexts. Firstly, *community of practice theory* recognises and respects the heterogeneity of disciplines and specialisations relevant to the interdisciplinary collaborative design of mHealth (physical activity) behaviour change intervention apps, and describes the overlapping shared boundary space where the diverse communities intersect. Secondly, *boundary object theory* emphasises the integral role and indispensable value of conceptual and material artefacts in guiding, facilitating, mediating and supporting the collaborative and heteropraxial design, development and evaluation activities of intersecting practice communities in shared boundary spaces of mHealth intervention app projects. Thirdly, *knowledge boundary theory* addresses the differences, dependencies and novelties that cause knowledge boundaries to arise between interdisciplinary collaborating team members on mHealth intervention app projects, and provides guidelines for overcoming these knowledge boundaries through communication, knowledge sharing/integration/generation, and the use of appropriate boundary objects. Together these three kernel theories provide a novel approach to guiding and supporting interdisciplinary collaborating teams in the design, development and evaluation process on mHealth (physical activity) behaviour change intervention app projects. Several figures were provided to illustrate, simplify and describe each of the three theories.

Lastly, the chapter concluded by highlighting the importance of theoretical frameworks in research, and provided a defence for the boundary object view as a suitable and appropriate pragmatic, sociomaterial, design and artefact orientated theoretical framework that is congruent with the philosophical, paradigmatic and DSR methodological tenets of this research project. Figure 5.9 provides a description, key concept and core construct summary of each kernel theory constituting the tri-composite theoretical framework, which will be used inform the lens for conducting a critical theoretical analysis on existing multi- and interdisciplinary digital health intervention development approaches (Chapter 6) and developing the DSR artefact contribution (Chapter 7).

## Tri-Composite Theoretical Framework: A Boundary Object View

### Community of Practice Theory

- Pragmatic perspective
- A community of practice is a group of individuals in a specific discipline or specialised domain who share knowledge and adopt a shared mental model or shared worldview in interpreting, understanding and making sense of reality.

- Differences in worldview perspectives
- Fragmented mental models
- Social learning systems

- Heterogeneous communities of practice
- Community of practice boundaries
- Community of practice actors/members
- Intersecting shared community space

### Boundary Object Theory

- Constructivist, pragmatic, sociomaterial and artefact perspective
- An abstract or concrete artefact in conceptual, material, symbolic and/or digital form
- A boundary objects sits in the middle of intersecting communities; satisfies minimum requirements; plasticity/robustness between local needs and common identity; weakly structured and common meanings in common use, and strongly structured and different meanings in individual-site use.

- Four main boundary object types
- Primary, secondary and tertiary boundary objects
- Design boundary objects
- Utility and value derives from actors' deliberate actions toward/interaction with objects

- Shared boundary space
  - Boundary actors: (1) Boundary workers; and (2) Boundary brokers
- Boundary crossing/spanning
- Boundary object core criteria:
  - (1) Interpretive flexibility
  - (2) Structure of informatics and work process needs and arrangements
  - (3) Dynamic between ill-structured and more tailored uses
- Other boundary object characteristics:
  - Abstractness/concreteness; respecting practice community boundaries; political and power dynamics, and neutrality; usefulness/utility, wholeness, accuracy and evolutionary remaking; and engineered artificiality

### Knowledge Boundary Theory

- Pragmatic perspective
- Knowledge is localised, embedded and invested in practice
- Knowledge boundaries arise due to differences, dependencies and novelties that arise between intersecting communities

- Knowledge sharing, knowledge integration and knowledge generation
- Pragmatic trade-offs, costs, power and status at stake, reluctance, resistance

- Relational knowledge properties:
  - (1) Difference; (2) Dependency; and (3) Novelty
- Progressively complex knowledge boundaries:
  - (1) Syntactic – differences in language, vocabulary and terminological usage
  - (2) Semantic – differences in interpretation and meaning
  - (3) Pragmatic – differences in interests and goals
- Progressively complex knowledge processes:
  - (1) Transfer; (2) Translation; and (3) Transformation
- Overcoming knowledge boundaries with boundary objects:
  - (1) Common language; (2) Common meanings; and (3) Common interests

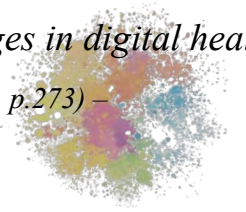
*Figure 5. 9: Summary of the Tri-Composite Theoretical Framework: A Boundary Object View [Source: Researcher's own construction]*

# Chapter 6

## A Critical Analysis of Multi- and Interdisciplinary Digital Health Intervention Development Approaches

*Throughout the whole lifecycle of developing, evaluating, implementing and exploiting digital health solutions, a multidisciplinary approach is required [and] crucial because everyone brings their own knowledge, experience, expertise and perspectives needed to address the diverse challenges in digital health.*

*– Bul, et al. (2020, p.273) –*



## 6.1 Introduction

The multidimensional design challenges and ongoing paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention apps has an impact on knowledge sharing and heteropraxial activity practices, and affects the process efficiency, project success and output product effectiveness of said apps (Sellak and Grobler, 2020; Sucala, et al., 2020). In response to this problem and knowledge gap, several multi- and interdisciplinary digital and mHealth intervention development approaches have been proposed in recent years. While none of the proposed existing approaches leverage the power and potential of boundary objects and artefacts as a useful means for facilitating and mediating knowledge sharing and heteropraxial praxes between interdisciplinary collaborating team members on mHealth (physical activity) behaviour change intervention app projects, they do provide valuable insights. Conducting a critical theoretical analysis on existing multi- and interdisciplinary digital health intervention development approaches can provide insight into the common key themes and subthemes relevant to guiding and supporting collaborating teams through the design, development and evaluation process of mHealth (physical activity) behaviour change intervention app projects.

This chapter starts by highlighting the importance of theorising and theory building in information systems and DSR projects, after which the role of cognitive reasoning strategies and theorising approaches is presented, and the congruous philosophical links between these elements is described. The theorising research approach used to conduct the critical theoretical analysis is then introduced, and the selected cognitive reasoning strategy and theorising approach is described in detail. Thereafter, using the cognitive reasoning strategy, the theorising approach and the boundary object view as a theoretical framework, a critical thematic and comparative theoretical analysis is conducted on a selected sample of twenty existing multi- and interdisciplinary digital intervention development approaches (grouped into four different perspective categories), and the common theme and subtheme findings are presented and discussed. The chapter concludes by summarising the key component theme and subtheme findings, which inform the development of a conceptual framework for guiding and supporting the interdisciplinary collaborative design of mHealth (physical activity) behaviour change intervention apps (Chapter 7).

The main aim of this chapter is to conduct a critical theoretical analysis of existing approaches in order to identify key common themes and subthemes that can be used to inform the first

iteration construction cycle of a novel DSR artefact in the form of an interdisciplinary framework. As illustrated in Figure 6.1, constructing an artefact falls within Step 3 ("artefact development") of the study's DSRM (outlined in Chapter 2). This chapter contributes to answering the third research sub-question: *"How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*.

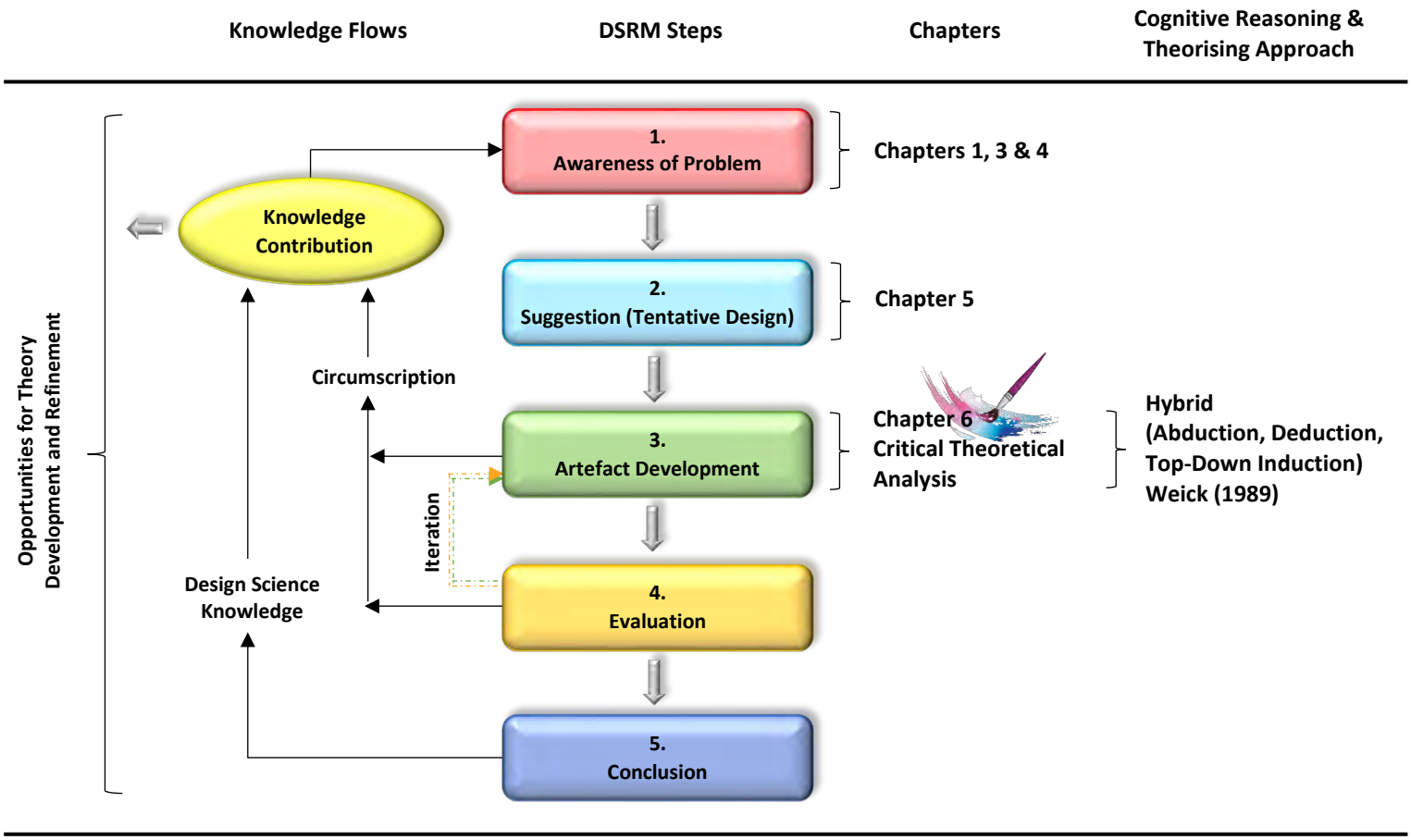



*Figure 6. 1: DSRM: Artefact Development: A Critical Theoretical Analysis [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 6.2 Theorising in an Information Systems Design Science Research Study

In the information systems discipline and the social sciences field, and in DSR studies in particular, theorising presents a challenging (Venable, 2006), yet "fundamental", research activity that adopts a "design orientated" approach to artefact construction (Gregory and

Muntermann, 2011, p.3). In DSR, theorising is generally challenging due to the "real world messy" (Nagle, et al., 2020, p.1) and "wicked" (Hevner and Chatterjee, 2010, p.11) nature of complex design problems, such as the case with this research project. Unlike the natural sciences, it is not possible to develop the "best" design theory (Truex, Holmström and Keil, 2006, p.814) or "optimal" design solutions (Lee, Pries-Heje and Baskerville, 2011, p.3). Instead, the theorising discovery and generation process aims to create design theory and design solutions that are "satisfactory" (Hevner and Chatterjee, 2010, p.188) or "satisficing" (Simon, 1996, p.119; Lee, Pries-Heje and Baskerville, 2011, p.4). Another consideration is that newly developed and proposed theory need not be fully complete, which is seldom realistic in research practice (Weick, 1995). Therefore, in information systems DSR, it is acceptable to produce "partial" and "nascent design theory" (Gregor and Hevner, 2013, p.342) that is "good enough" or "better than before" (Martinsons, Davison and Ou, 2015, p.14).

*Theorising* is a "messy but… fruitful", purpose-driven and goal-orientated process that uses cognitive discovery, analysis and reasoning as well as creative thought processing to generate and build new theory (Lee, Pries-Heje and Baskerville, 2011; Schneiderhan, 2016, p.43). Weick (1989, p.516) defines theorising as a "disciplined imagination", where *discipline* is practised through the "consistent application of selection criteria to trial-and-error thinking", and *imagination* is employed in the deliberate diversity introduced into the problem statements, thought trials and selection criteria that constitute trial-and-error thinking. Theorising is a pragmatic exercise that many researchers often resist; however, it is necessary for a researcher to explicitly articulate and justify how they "put together [and] handle[]" theory (Swedberg, 2016, p.6). This requires the researcher to explicitly articulate and justify their selection of cognitive reasoning strategies, tools and activities used to build theory. Three predominant logical cognitive reasoning and processing strategies are abduction, deduction and induction (Gregory and Muntermann, 2011). Three common mental tools are description, abstraction and generalisation (Swedberg, 2017). Some theorising activities include relating, selecting, explaining, synthesising and idealising (Weick, 1995).

While there exists no optimal or universally-accepted theorising approach, Weick's (1989) three-component process has become a credible, reliable and widely-applied approach in pragmatic and design problem orientated information systems DSR studies (Gregory and Muntermann, 2011; Lukyanenko and Parsons, 2013; Mandviwalla, 2015; Mthoko, 2016; Mueller and Urbach, 2017; Baduza, 2020). Philosophically, Weick's (1989, p.156) theorising

approach is “analogous to artificial selection”; a pragmatic process that allows a researcher to apply a theory-driven approach to analysis, and use an artificial selection of constructs (informed by the theoretical framework, a boundary object view), to guide the development of new (partial) design theory and a novel satisficing design artefact solution. This demonstrates compatibility between Weick’s (1989) pragmatic theorising approach and the research study’s pragmatic paradigm (presented in Chapter 2).

Articulating the assumptions and philosophical ties underlying the critical theoretical analysis and the selection of cognitive reasoning strategies, tools and activities is also important to demonstrate the researcher’s critical reflexivity and the credibility of the theorising process (Martinsons, Davison and Ou, 2015). In terms of the critical theoretical analysis assumptions: (1) the researcher is primarily motivated to find a solution to a problem where (1.1) they experience doubt over current habits (doubt over existing approaches for guiding interdisciplinary collaborative design thought and action) and where (1.2) the outcome theory may be fallible and is open to revision upon evaluation and the revealing of new information; (2) the researcher oscillates between unconscious habits and more conscious creativity and logical thought processing; and (3) the researcher is aware that their own mental models, background knowledge and past experiences influence their perceptions and interpretations of the problem and solution environment (Dewey, 1910; Peirce, 1931; 1934; 1935; Shepherd and Sutcliffe, 2011).

Philosophically, theorising strategies such as abduction and top-down induction are grounded in pragmatism (Peirce, 1934; Shepherd and Sutcliffe, 2011), which is congruent with the research project’s pragmatic paradigm. In terms of the critical theoretical analysis, critical reflexivity is practiced through an awareness of the philosophical perspectives adopted, namely the pragmatic, sociomaterial, symbolic interactionist, artefact and design perspectives, and an understanding of the harmony between the tenets and assumptions of these perspectives (Orlikowski, 2007; Goldkuhl, 2012b; Carlile, et al., 2013; Saunders, Lewis and Thornhill, 2016). To rephrase in relation to the study context, the mHealth intervention consumer app and the app product design solution emerges from a complex entanglement of social, relational, material and symbolic interactionism between heterogeneous collaborating community of practice actors and the artefacts that they employ and utilise during the interdisciplinary mHealth behaviour change intervention app project and process (in practice).

## 6.3 The Theorising Research Approach

The theorising research approach used to conduct the critical theoretical analysis employs a hybrid cognitive reasoning strategy (combining abductive, deductive and top-down inductive processing) nested within Weick's (1989) three-component theorising approach (illustrated in Figure 6.1). The purpose and intention behind using this theorising approach is so that researcher is provided with a credible, reliable and structured guide for performing a rigorous, good quality critical theoretical analysis that supports the investigation, identification and elicitation of components (themes and subthemes) relevant to the research objective (demonstrating the rigour and relevance cycle in DSR; Chapter 2, Section 2.3.4). Explicitly articulating and describing the theorising research approach enhances the transparency and trustworthiness of the critical theoretical analysis findings, and strengths the theoretical and evidence base upon which the conceptual framework (artefact) is developed in Chapter 7.

The theoretical base of the conceptual framework is also strengthened through justificatory knowledge, which provides a basis and explanation for the design (kernel theories) (Gregor and Jones, 2007). In conducting the critical theoretical analysis, *process* kernel theories (theories from social or natural sciences that inform the theoretical framework and design process) are evidenced by the tri-composite theoretical framework, comprising community of practice, boundary object and knowledge boundary theory (Walls, Widmeyer and Sawy, 1992; Gregor and Jones, 2007). *Product* kernel theories (theories from social or natural sciences that govern the design artefact's requirements and construction) include theories, concepts and constructs extracted, interpreted, contextualised, themed and categorised from multi- and interdisciplinary digital health intervention development approaches existing in the knowledge base (Walls, Widmeyer and Sawy, 1992; Gregor and Jones, 2007; Vaishnavi, Kuechler and Petter, 2017). Both kernel theories are important for building new information systems DSR design theory (Gregor and Jones, 2007; Vaishnavi, Kuechler and Petter, 2017).

### 6.3.1 A Hybrid Cognitive Reasoning Strategy

A novel hybrid cognitive reasoning strategy, combining abductive, deductive and top-down inductive thought processing, is employed when conducting the critical theoretical analysis. A "hybrid" cognitive reasoning strategy, described as comprising two or three reasoning processes, is useful for leveraging the strengths and mitigating the weaknesses of each strategy, whilst remaining open-minded to the creative and innovative thought processing typically

required for addressing wicked design problems (Fereday and Muir-Cochraine, 2006, p.83; Gregory and Muntermann, 2011, p.14; Braun and Clarke, 2012; Swain, 2018, p.7).

*Abductive reasoning* is essential to the design theorising and knowledge generation process because it allows a design science researcher to propose a "satisficing explanation" (Lee, Pries-Heje and Baskerville, 2011, p.4) that draws an "inference to the best explanation" (Harman, 1965, p.88). Moreover, when used in conjunction with deductive and inductive reasoning, it aids the researcher's cognitive trial-and-error "internal falsification" experiments, and guides the analytical narrowing, scoping, refining and clustering of themes and subthemes relevant for informing the development of a design artefact solution and design knowledge contribution (step 3, Figure 6.1) (Timmermans and Tavory, 2012, p.180). *Deductive reasoning* is employed so that the tri-composite theoretical framework (boundary object view) (proposed in Chapter 5 as the tentative design solution) provides process kernel theory that frames the template criteria for critically analysing the existing multi/interdisciplinary digital health intervention development approaches.

Applying *top-down inductive reasoning* allows the critical analysis to be conducted using a preliminary tentative idea (boundary object view; aligning with abductive reasoning) and avoids 'reinventing the wheel' by analysing and inducing product kernel theory from secondary (rather than primary) data with the intention of extracting themes relevant for informing the conceptual framework's development (Shepherd and Sutcliffe, 2011). Furthermore, top-down induction offers a dynamic cognitive processing activity similar to Weick's (1989) concept of "disciplined imagination", where trail-and-error thought experiments and deliberate diversity helps focus the researcher's attention when comparing sensory and conceptual representations, leading to iterative and progressive adjustments and refinements as greater coherence between the two representations is achieved (Shepherd and Sutcliffe, 2011). Moreover, top-down induction is consistent with the principles of Weick's (1989) theorising approach in terms of creativity, speculative thought and conceptual mapping (Shepherd and Sutcliffe, 2011).

For the reasons described above, the novel hybrid cognitive reasoning strategy provides a useful and appropriate thought processing lens for conducting the critical theoretical analysis. The hybrid cognitive reasoning strategy is nested within Weick's (1989) theorising approach. Deductive reasoning carries a relatively heavier weighting than the abductive and top-down inductive thought processes because the theoretical framework (boundary object view) essentially steers the critical analysis and theme extraction process. This relative predominance

of one reasoning over another (or two others in this case) is acceptable in information systems DSR theorising (Gregory and Muntermann, 2011; Braun and Clarke, 2012). For further detailed descriptions of each of three cognitive reasoning processes constituting the hybrid strategy, refer to Chapter 2 (Subsection 2.3.3.2). Considering that the hybrid cognitive reasoning strategy is applied in both Chapter 6 and Chapter 7, it was introduced, described and justified in further detail in the research structure (Chapter 2).

### 6.3.2 Weick's Theorising Approach

Weick's (1989) theorising approach is employed as the main process for conducting the critical theoretical analysis. Weick's (1989) theorising process consists of three components, namely: (1) *problem formulation*, (2) *thought trials*, and (3) *selection criteria*. These components operate concurrently and iteratively throughout the critical analysis (Lee, Pries-Heje and Baskerville, 2011); behaving similarly to the hybrid cognitive reasoning and creative thought processing strategies encapsulated within these components. Weick's (1989, p.516) theorising approach rests on the premise that theory building is a form of "disciplined imagination". To reiterate the description provided in Section 6.2, *discipline* is practised through the "consistent application of selection criteria to trial-and-error thinking", and *imagination* is employed in the deliberate diversity introduced into the problem statements, thought trials and selection criteria (namely the three components) that comprise trial-and-error thinking (Weick, 1989, p.516).

Weick's (1989, p.519) theorising approach proposes a "sensemaking", rather than a conventional linear problem-solving, perspective through the flexible practice of disciplined imagination and trial-and-error thought processing. This allows the researcher to (1) "make sense" of the complex and wicked interdisciplinary design problem and solution environment, (2) establish loosely coupled definitions and relationships between concepts, constructs and the context of interest (present in the product kernel theories), and (3) align the theoretical framework (boundary object view) with their attention focus in the real world (Weick, 1989, p.519). Weick's (1989, p.519) approach also acknowledges the value and role intuition, creativity, imaginary experimentation and artificiality play in the often "blind [and] serendipitous" theorising process. The application of such subconscious (intuitive) and conscious (cognitive and creative) activities and thought processes are highlighted as "pivotal" in building information systems DSR theory and quality design artefacts (Lee, Pries-Heje and Baskerville, 2011; Fischer, Gregor and Aier, 2012, p.4; Alturki and Gable, 2014).

Figure 6.2 outlines Weick's theorising approach used to conduct the critical theoretical analysis, highlighting the three components: (1) *problem formulation*, (2) *thought trials*, and (3) *selection criteria*. The subsections following Figure 6.2 thoroughly describe and detail each component.

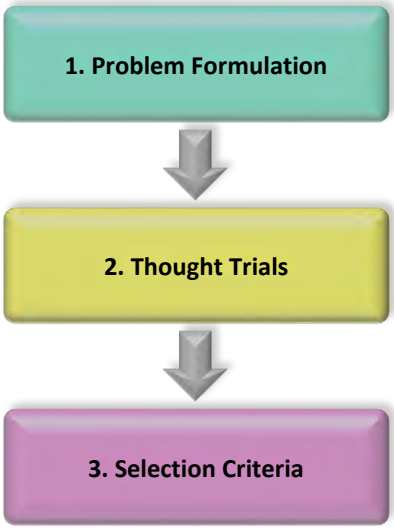



*Figure 6. 2: Weick's Theorising Approach used to Conduct the Critical Theoretical Analysis [Source: Researcher's own construction, informed by Weick (1989)]*

#### 6.3.2.1 Problem Formulation

Theory development in DSR is influenced by the need to "make sense" of and address a wicked design problem (Weick, 1989, p.519), which requires a researcher to first establish an "intimate familiarity with the problem domain [because] *problem formulation* and theory building go hand in hand" (Van de Ven, 2007, p.100). Weick's (1989) theorising approach is useful for addressing artificial (rather than natural) problems, which are formulated by the researcher's interpretations and evolutionary intentional, intuitive and exploratory understanding of the real world messy design problem environment (Simon, 1996; Nagle, et al., 2020). In other words, explicating and formulating the artificial DSR design problem (and proposing a satisficing design solution) is a human sensemaking and judgement-making process chiefly influenced by the researcher's perspectives and interpretations of the complex and ill-defined design problem environment (Checkland, 2000; Lee, Pries-Heje and Baskerville, 2011). Wicked design problems (and their proposed design solutions) can be perceived and interpreted differently by different people, and these perceptions and interpretations are fluid and transformable (Venable, 2006). It is therefore imperative that the problem statement be elucidated in an intelligible and transparent manner (Weick, 1989).

Elucidating the problem statement requires that the researcher transparently communicate the way in which the problem environment and specific problem of interest has been perceived, interpreted, contextualised, scoped and defined (Gregory and Muntermann, 2011). The richness and nuanced complexities embedded in the problem formulation emerges from the researcher's past experience(s), tacit knowledge and comprehensive grasp of the relevant interdisciplinary literature, which is conveyed in (1) *the research chapters* (Weick, 1989). Further richness and transparency of the problem formulation originates from the researcher's: (2) *explicit articulation of their implicit assumptions*, (3) *descriptions of key problem (and solution) terminology* and (4) *identifications and justifications for perspectives adopted in framing their perception and structuring of the problem* (Weick, 1989; Gregor and Jones, 2007; Gregory and Muntermann, 2011). According to Weick (1989), this richness allows for more criteria than validation to become relevant to the theorising process.

***Research Chapters Elucidating the Problem Formulation***

The researcher's several years of experience with substantial literature contributes to the identification of gaps and motivates the need to develop an interdisciplinary collaborative framework for mHealth (physical activity) behaviour change intervention app projects. Table 6.1 highlights how Chapters 1 to 5 have contributed to the problem formulation as well as the future contributions for selecting the approaches sample in the critical theoretical analysis.

*Table 6. 1: Research Chapters Elucidating the Problem Formulation*
*[Source: Researcher's own construction]*

| Chapter | Contribution to Problem Formulation |
|---|---|
| **Chapter 1: Research Introduction** | The research problem is outlined and situated in its appropriate study context. |
| **Chapter 2: Research Structure** | The overall research approach applied to address the research problem is described. |
| **Chapter 3: The Health Landscape: Health Promotion and the Physical Activity Domain** | The current global status on noncommunicable diseases and modifiable health risk behaviours is discussed. The need for health promotion behaviour change interventions targeting the dual intra-interpersonal socioecological level is emphasised. The key challenges and components associated with the design of dual intra-interpersonal physical activity behaviour change interventions are discussed. The physical activity health behaviour problem context is highlighted. |
| **Chapter 4: Digital mHealth: Using Technology to Deliver Health Promotion Interventions for Physical Activity Behaviour Change** | The opportunities and challenges of leveraging digital mHealth technology, and particularly mobile consumer apps, as a platform for delivering intra-interpersonal health behaviour change interventions are discussed. The challenges and need for collaboration and integration between health and technology are presented. The key |

| | |
|---|---|
| | design challenges of mHealth physical activity behaviour change intervention apps targeting the dual intra-interpersonal socioecological level are discussed. The need for multi- and interdisciplinary approaches is introduced. A preliminary critical review reveals key challenges and gaps of existing approaches. |
| **Chapter 5: A Boundary Object View to the Interdisciplinary Collaborative Design of mHealth Behaviour Change Intervention Apps** | The need for a boundary object view (comprising community of practice, boundary object and knowledge boundary theory) to guide and support the interdisciplinary collaborative design of mHealth (physical activity) behaviour change intervention apps is highlighted. |

### *An Explicit Articulation of Implicit Assumptions*

Artificial and wicked design problems by their inherent nature involve "so many" assumptions and constitute such an entangled mixture of accuracy and inaccuracy that "virtually all conjectures and all selection criteria remain plausible, [so that] nothing gets rejected or highlighted" (Weick, 1989, p.521). To overcome this challenge, the principles of middle range theories, which contain a limited number of assumptions and sufficient accuracy and detail, are useful for scoping the problem to a manageable size (Weick, 1989). Explicitly articulating the assumptions enhances the theorising process's credibility. Box 6.1 outlines the assumptions held by the researcher when formulating the problem and conducting the critical analysis:

**Assumptions Held During the Problem Formulation and Critical Analysis**

- Design, as a pragmatic activity, is viewed as heteropraxial in nature (Bertelsen, 2000).
- Design (as a verb and noun) lies at the heart of the interdisciplinary collaborative project process and the product output.
- The heterogeneous community of practice actors in any given mHealth intervention app project are aware of and willing to work together. If unaware, they are assumed as being willing to learn.
- The collaborating heterogeneous community of practice actors of any given mHealth intervention app project are aware and cognisant of the shared design problem space.
- When meaningfully enacted with and used, boundary objects and design artefacts can provide a utile means of sharing design knowledge and heteropraxial activities during the interdisciplinary collaborative design, development and evaluation process.
- The mobile (smartphone and tablet) app platform provides a powerful and "important delivery vehicle" for delivering mHealth physical activity behaviour change interventions targeting the dual intra-interpersonal socioecological level (Helf and Hlavacs, 2016, p.21).

*Box 6. 1: Assumptions Held by the Researcher During the Problem Formulation and Critical Theoretical Analysis [Source: Researcher's own construction]*

***Key Problem (and Solution) Terminology***

Defining the key terminology with regard to the problem formulation (and solution) is important for the problem formulation and critical theoretical analysis since it clarifies how the problem of interest is perceived and interpreted by the researcher (Gregor and Jones, 2007). Table 6.2 outlines the key terminology, particularly relevant to the concept of design.

*Table 6. 2: Key Problem (and Solution) Terminology [Source: Researcher's own construction, informed by Bertelsen, 1998; 2000; Reymen and Basten, 2002; Reymen, et al., 2006; Bergman, Lyytinen and Mark, 2007; Gaskin, et al., 2011; and Langley, Wolstenholme and Cooke, 2018)]*

| Terminology | Definition Particularised to the Problem (and Solution) |
|---|---|
| **Design (as a noun)** | The material design of a mHealth (physical activity) behaviour change intervention app (as an object) in proof-of-concept, building, working or final prototype forms. |
| **Design (as a verb)** | The process practices (including steps and activities) performed by an interdisciplinary collaborating team in conceptualising, materialising, developing and evaluating a mHealth (physical activity) behaviour change intervention app (as an object). |
| **Design knowledge** | Heterogeneous knowledge relevant to the design (object) and designing (process) of a mHealth (physical activity) behaviour change intervention app (as an object). Design knowledge can be in the form of constructs, theories, models, methods, processes, practices and activities, and can be tacit, explicit, objective, subjective, emotional or socio-cultural in nature. During the design process (verb), design knowledge expands and confines, and over time comes to reside within the app's final design (noun), and embodied in the design attributes, software features and intervention functionalities. |
| **Design process** | A (sequential, non-sequential and/or iterative) series of design steps and design activities that guide and support interdisciplinary collaborating teams during the design, development and evaluation activities of an mHealth intervention project; from the app's initial conception to its final product release version. |
| **Design step (stage or phase)** | The main high-level (sequential, non-sequential, concurrent and/or iterative) steps constituting the interdisciplinary collaborative design, development and evaluation project process. Each step comprises several design related activities. |
| **Design activity** | A design activity is enacted when a design subject (an interdisciplinary collaborating team actor) shapes the design object (mHealth (physical activity) behaviour change intervention app) through the use of design knowledge, design artefacts and design boundary objects. |
| **Design artefact** | Objects used by various community of practice actors to perform design activities relating to the design of a mHealth (physical activity) behaviour change intervention app (as an object). |
| **Design boundary object** | A shared (interpretatively flexible, plastic, dynamic and malleable) object that facilitates and mediates design knowledge sharing and heteropraxial design activities between interdisciplinary collaborating team members in the context of a particular shared design problem and design situation. |
| **Object of design** | The final output product of the interdisciplinary collaborative design, development and evaluation project process, produced in the form of a mHealth (physical activity) behaviour change intervention app (as an object). |

Additional design related terminology includes the design problem, design situation, design context, design task, design routine, design path, and design solution (Bertelsen, 1998; 2000; Reymen and Basten, 2002; Reymen, et al., 2006; Gaskin, et al., 2011; Langley, Wolstenholme and Cooke, 2018). Tying together the key and additional design problem (and solution) terminology sheds light on the multiplex and complex interconnected dynamics evident in the problem formulation. Chiefly, the specific design problem, design situation and design context, and the interdisciplinary collaborating actors' design knowledge, design praxes and suggested design solutions, as well as the uncovered design issues, ambiguities, disagreements and resolutions thereof, all influence the realised design activities, design tasks, design routines, design path and overall enacted interdisciplinary design process. Furthermore, the design artefacts and design boundary objects employed throughout the whole design process, and hence employed to carry out various design activities and design tasks (within each design step), differs depending on the design knowledge, expertise and skills of the interdisciplinary collaborating team members as well as the design problem, design situation and design context. Therefore, depending on the interdisciplinary collaborating team members' selections, interpretations and pragmatic uses of design artefacts and design boundary objects at different points (design steps, activities and tasks) of the interdisciplinary design process (as a verb), the output object of design (as a noun) can vary significantly. Moreover, mHealth intervention app project interdisciplinary collaborating teams address design specific problems in different ways. Depending on the project's design goal, design situation and design context, the team's combined design knowledge, and particular design process steps, activities and tasks performed by the team, there exists a plethora of possible case- and context-specific instances, all of which require different design solutions. However, at the same time, there neither exists a single, optimal design solution that can be fully replicated in different instances, nor is there any 'perfect' design artefact and design boundary object available for all interdisciplinary collaborating teams to employ and use in any and every possible design instance.

The above descriptions illuminate the multiplex and complex interconnected dynamics evident in the wicked nature of the artificial design problem environment. Over and above this complexity is recognising that design problems exist on a meta-level (in terms of the problem formulation) and on a micro-level (in terms of the instance-specific case of a mHealth physical activity behaviour change intervention app project). Unpacking the key and additional problem (and solution) terminology helps clarify the problem formulation process, enriches the

researcher's understanding of the problem environment, and enhances the critical theoretical analysis and theorising (theory building) process.

***Perspectives Adopted in Framing the Problem Formulation (and Solution)***

As outlined in Section 6.2, the critical theoretical analysis (and research project in general) adopts pragmatic, sociomaterial, symbolic interactionist, artefact and design orientated perspectives to understanding the problem environment. These perspectives complement the philosophical underpinnings of the tri-composite theoretical framework (boundary object view) and the proposed DSR artefact solution (the interdisciplinary framework). These perspectives, and their congruent philosophical bases, were described in Chapter 2 (Section 2.2.1), and hence will not be reiterated in this discussion. The main reason for demonstrating an awareness of these perspectives is that they essentially influence how the researcher (1) understands and interprets the problem environment, (2) formulates the problem statement, and (3) analyses, critiques and makes sense of the existing multi- and interdisciplinary digital health intervention development approaches (sampled secondary dataset) when performing the critical theoretical analysis.

***Problem Formulation Summary***

In short, Section 6.3.2.1 has described the first component of Weick's (1989) theorising approach, and has elaborated on the sub-components constituting the problem formulation. This demonstrates the researcher's "intimate familiarity with the problem domain" and gives credibility to both the critical theoretical analysis and the theorising process (Van de Ven, 2007, p.10). Figure 6.3 summarises the key points of the problem formulation in this critical analysis.

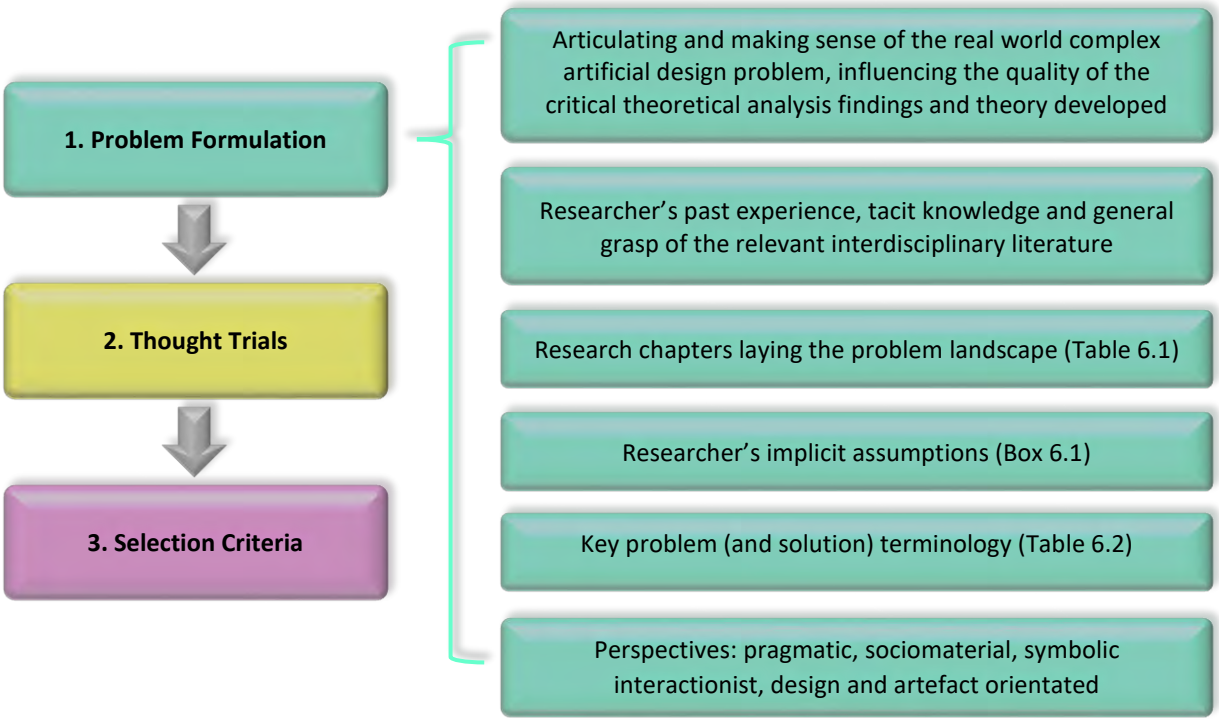



*Figure 6. 3: Weick's Theorising Approach: Problem Formulation Summary [Source: Researcher's own construction, informed by Weick (1989)]*

### 6.3.2.2 Thought Trials

To solve artificial design problems, theorists generate conjectures using a mental tool referred to as *thought trials*, which in theory building, describes a highly iterative and evolutionary trial-and-error process of thought experiments that cultivate and transpire in the mind of the researcher (Weick, 1989). Unlike practical laboratory experiments that are materially applied in the outside world, thought trials (in the information systems and DSR theorising process) form the basis for the conceptual and progressively refined development and testing of an imaginary, creative and innovative artefact solution in the researcher's mind (Weick, 1989; Lee Pries-Heje and Baskerville, 2011). By practising "imaginary experiments" (Weick, 1989, p.519), a theorist embarks on a journey of discovering, designing, conjecturing, evaluating, retaining, refuting and refining copious, albeit indefinitely numbered, artificial experiments in their own mind (Lee, Pries-Heje and Baskerville, 2011). Thought trials (conjectures) and errors (refutations) are artificial in that their conceptual creation, revision and confutation contain elements of researcher selection bias, perception bias and subjective interpretation, rather than being based on nature as a separate and purely objective reality (Smit, 2012). Therefore, to maintain a credible theorising process, thought trials and intuitions need to be explicitly articulated (Weick, 1989).

Theory plays an integral role in explicating the theorising process, for "without theory, there will be no theorising" (Swedberg, 2016, p.12). Theory and theoretical concepts help a researcher to cognitively interpret and make sense of analysed data samples since researchers "simply cannot see the world without concepts" (Carleheden, 2016, p.40). Clarifying key concepts and terminology is therefore important – as demonstrated in Table 6.2. Furthermore, Kant (1922, p.41) asserts that "thoughts without contents are empty, intuitions without concepts are blind". This quote encapsulates "the togetherness principle" (Hanna, 2011, p.403); that is, the necessary complementary and semantic interdependence between human concepts (sensemaking content) and human intuitions (sensory perceptions). Intuitions are sensory perceptions (empty thoughts), which without understanding (concepts as rational mental structures) are meaningless, and mental concepts without intuitive sense perceptions (non-conceptual cognitions) are blind (Hanna, 2011). Together these elements constitute human cognition and knowledge (Kant, 1922). Therefore, to ensure a good quality critical theoretical analysis and thought trial process, the researcher practices a combination of disciplined imagination and human creativity, together with sensory perceptions (human intuitions) and theory (human cognitive sensemaking content and concepts).

Along with a clarified understanding of key concepts and the integral role of disciplined imagination, creativity, intuition and theory in developing (information systems) design theory, Weick (1989) highlights the significance of *heterogeneity* when generating conjectures and conducting thought trials. Weick (1989) argues that diversity in thought trials prevents narrow habituated thinking and produces better theory that is more likely to solve problems, than homogeneous thought trials. This notion is supported by Truex, Holmström and Keil (2006), who describe heterogeneity as core to the evolution of the information systems field, and emphasise diversity in theoretical underpinnings and kernel theories as integral to information systems design theorising and better design theory development. Therefore, richness derives from the mindful borrowing and adapting of multiple theories – in the form of process and product kernel theories – from a range of diverse knowledge domains (Walls, Widmeyer and Sawy, 1992; Weick, 1989; Truex, Holmström and Keil, 2006; Vaishnavi, Kuechler and Petter, 2017). The applied hybrid cognitive reasoning strategy, together with a diverse selection of process and product kernel theories, further enriches the thought trials, analysis findings and proposed artefact design solution.

Process kernel theories frequently originate from outside the information systems discipline, and propose novel solution perspectives to information systems design problems (Kuechler and Vaishnavi, 2008). Borrowing and adapting diverse, albeit compatible, process kernel theories enriches the thought trial and theorising process (Weick, 1989). In the critical theoretical analysis, the three kernel theories employed – namely community of practice, boundary object and knowledge boundary theory – originate from external disciplines, including anthropology, sociology, zoology, vertebrate biology, management and organisational sciences (Lave, 1988; Star and Griesemer, 1989; Carlile, 2004; Wenger, 2010). The tri-composite theoretical framework (process kernel theory) provides a deductive and abductive lens, which together with disciplined imagination, creativity and intuition, can guide the thought trials towards constructing new design theory and an innovative design artefact solution.

Heterogeneity in product kernel theories provide a greater diversity of higher quality thought trials in theorising and developing a novel artefact solution (Weick, 1989). In the critical analysis, the sampled multi- and interdisciplinary digital health intervention development processes span several relevant disciplines, such as health psychology, health sciences, health behaviour change, information systems, persuasive systems design, physical activity, mobile development, and more. This diversity enriches the thought trials and analysis findings, and strengthens the theoretical and internal grounding of the new artefact solution (Weick, 1989).

Conducting thought trials with abductive reasoning allows the researcher to perform "internal falsification" so that the most plausible components of existing multi- and interdisciplinary digital health intervention development approaches (secondary data) can be extracted to inform the construction of a satisficing design theory and design artefact solution (Gregory and Muntermann, 2011; Timmermans and Tavory, 2012, p.180). Abductive reasoning also allows the researcher to be guided by their "guessing instinct" when conducting trial-and-error imaginary experiments (Weick, 1989; Paavola, 2006, p.68). Moreover, conducting thought trials with top-down inductive reasoning allows the researcher to induce valuable findings from the sampled multi- and interdisciplinary approaches, which are already theory and evidence based and have already been verified, therefore further strengthening the new artefact solution and avoiding 'reinventing the wheel'.

### *Thematic Analysis Approach to Critical Theoretical Analysis and Thought Trials*

A thematic analysis of existing multi- and interdisciplinary digital health intervention development approaches (product kernel theories) framed by the tri-composite theoretical framework, boundary object view (process kernel theories), is applied to identify, sort and clarify the key components (themes and subthemes) necessary and relevant to interdisciplinary collaborative mHealth (physical activity) behaviour change intervention app projects. Conducting thought trials with a thematic analysis provides a qualitative method for extracting, organising and making sense of commonalities and patterns in existing approaches (Weick, 1989; Braun and Clarke, 2012). The thematic analysis method offers several advantages, particularly in terms of flexibility (Braun and Clarke, 2012). This flexibility allows the hybrid cognitive reasoning strategy to be embedded within the thought trials and thematic analysis. More specifically, the deductive boundary object theoretical framework predominantly guides the identification of themes and subthemes, while abductive reasoning seeks the best and most plausible explanations, and top-down inductive reasoning allows unanticipated findings to emerge from the secondary dataset. In addition, flexibility permits the investigation of both apparent and latent themes in the dataset; the latter of which allows the exploration of community of practice, boundary object and knowledge boundary themes that are neither explicitly stated nor consciously recognised by the dataset authors (Guest, MacQueen and Namey, 2012). For example, authors may discuss app prototypes, but not recognise their boundary object functionality. Considering the novelty of the proposed boundary object view, flexibility is imperative to performing a quality thematic analysis with rich thought trials.

Braun and Clarke's (2006) widely applied and reliable *six-step thematic analysis* approach is applied to conduct the critical theoretical analysis. Within this approach, *comparative analysis* is employed as a method for comparing similarities and differences between themes and subthemes identified in the multi- and interdisciplinary digital health intervention development approaches (Corbin and Strauss, 2015). The comparative trial-and-error thinking and thought trials function concurrently with the hybrid cognitive reasoning strategy, and the tri-composite theoretical framework (boundary object view) predominantly guides the thematic and comparative analysis. Jointly, this describes a *critical thematic and comparative theoretical analysis approach*. Table 6.3 outlines the critical thematic and comparative theoretical analysis approach used to analyse a sample selection of multi- and interdisciplinary approaches.

*Table 6. 3: Critical Thematic and Comparative Theoretical Analysis Approach [Source: Researcher's own construction, adapted from Braun and Clarke (2006) and Corbin and Strauss (2015)]*

| Step | Description |
|---|---|
| **1. Become familiar with the data** | Actively read, re-read and analyse the existing multi- and interdisciplinary digital health intervention development approaches. Take notes on any initial apparent and latent ideas as well as possible patterns relevant to the boundary object view. |
| **2. Generate initial codes** | Systematically analyse and code features that appear interesting across the existing multi/interdisciplinary approaches. Comparatively analyse similarities and differences in codes. Use the template criteria (Table 6.5) to generate and compare codes, and group relevant data to each code. |
| **3. Search for themes and subthemes** | Based on the initial codes, actively explore, generate, compare and organise themes and subthemes into meaningful patterns. Collate all relevant data in relation to each candidate theme and subtheme. |
| **4. Review themes and subthemes** | Review each candidate theme and subtheme in relation to the collated coded data and the entire dataset, and confirm coherent patterns. Theme and subtheme refinement may lead to some being created and/or merged and others being separated, rearranged and/or discarded. Draw a thematic map to outline the themes and subthemes, and their relationships. |
| **5. Define and name themes and subthemes** | Name, define and refine the details of each theme and subtheme in relation to the boundary object view. Clearly capture the essence, story, boundaries and what is interesting about each theme and subtheme. Refine the overall analysis story. |
| **6. Write the thematic report** | Write and produce a report on the thematic analysis findings, detailing the meaningful story of the data in relation to the boundary object view. Map the findings back to the research questions and use the findings to inform the development of the proposed interdisciplinary framework (Chapter 7). |

***Thematic Analysis and Thought Trial Diversity: Heterogeneity in Product Kernel Theories***

Given the interdisciplinary nature of the problem and solution environment, incorporating diversity in thought trials is essential for producing rich thematic findings (Weick, 1989; Jabareen, 2009). Heterogeneity is applied when selecting existing multi- and interdisciplinary digital health intervention development approaches to critically analyse. When building a multi/interdisciplinary conceptual framework, Jabareen (2009, p.57) discusses the importance of drawing theories from multiple relevant disciplines because the theory "become[s] the empirical data of the conceptual framework analysis". This allows the critical thematic and comparative theoretical analysis to produce findings that consider and include knowledge, expertise and practices from a heterogeneity of perspectives. Furthermore, as part of the critical

analysis and conceptual framework development process, Jabareen (2009) pinpoints the value in categorising the secondary data by a key distinguishing feature. In sorting through the available multi- and interdisciplinary approach literature, the researcher chose to categorise the secondary dataset into four overarching perspectives, namely: (1) a *Health Sciences Perspective*, (2) an *Information Systems and Technology Perspective*, (3) a *Partnership Perspective*, and (4) an *Integrative Perspective*. Figure 6.4 outlines these four perspective categories and details the subcategories and descriptions of each perspective.

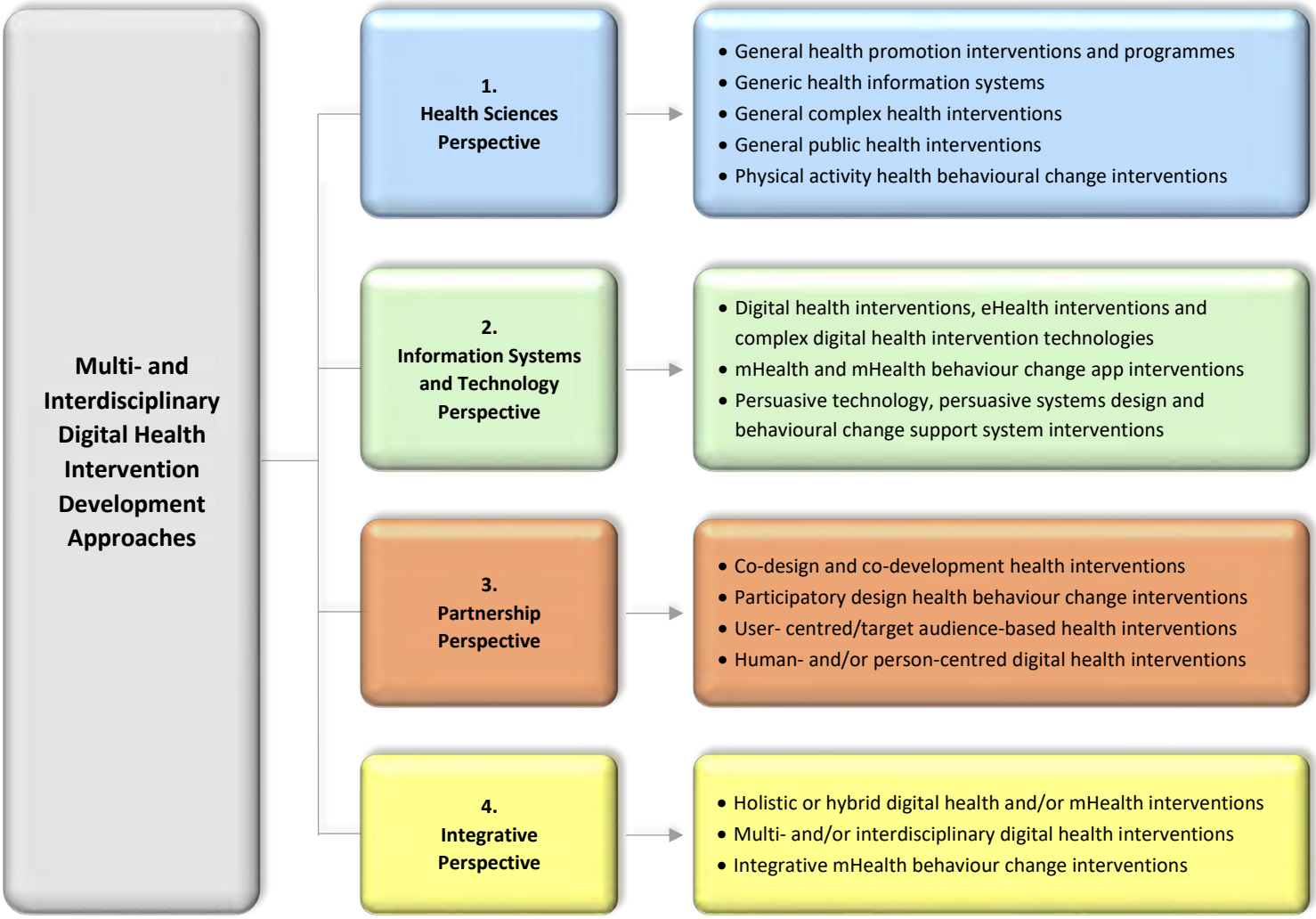



*Figure 6. 4: Four Perspective Categories of Multi- and Interdisciplinary Approaches Reviewed in the Critical Thematic and Comparative Theoretical Analysis [Source: Researcher's own construction]*

Important to note is that although the researcher categorises the sample selected multi- and interdisciplinary digital health intervention development approaches under the four perspective categories, none of the approaches can be singularly siloed as offering one distinct perspective. As a matter of fact, all of the multi- and interdisciplinary approaches incorporate multiple

perspectives informed by different knowledge, expertise and practices from a heterogeneity of disciplines and specialisations. However, at the same time, each approach holds one predominant perspective that is clearly and explicitly conveyed by the approach author(s). The predominant perspective held by an approach determines which of the four perspectives it is categorised under.

For example, *The Behavioural Intervention Technology (BIT) Model* is described by Mohr, et al. (2014, p.1) as an "integrated conceptual and technological framework for eHealth and mHealth interventions" and a "hybrid framework" that aims to "bridge the fields of [health] behavioural science and technology". On the surface, words such as "integrated" and "hybrid" may have one assume *The BIT Model* falls under the "Integrative Perspective" category (Figure 6.4). However, upon careful review of *The BIT Model* and its components, it is apparent that the framework is built on persuasive technology and persuasive systems design models, provides specific guidance for designing and developing the technical characteristics, workflows and instantiations of e- and mHealth interventions, and incorporates a proposed "a technological framework (*BIT-Tech*). The technological perspective outweighs the integrative and hybrid perspective, and thus *The BIT Model* is classified under the "Information Systems and Technology Perspective" category. The same approach to categorisation was applied for all of the multi- and interdisciplinary approaches selected for inclusion in the critical analysis.

***Thought Trials Summary***

In short, Section 6.3.2.2 has described the second component of Weick's (1989) theorising approach, and has elaborated on the elements constituting thought trials. This demonstrates the mental tool the researcher uses to generate conjectures and practice trial-and-error imaginary experiments when conducting the critical thematic and comparative theoretical analysis, in order to produce better design theory and a richer innovative design solution artefact, as well as give credibility to the critical analysis and theorising process. Figure 6.5 summarises the key points of the thought trials in this critical analysis.

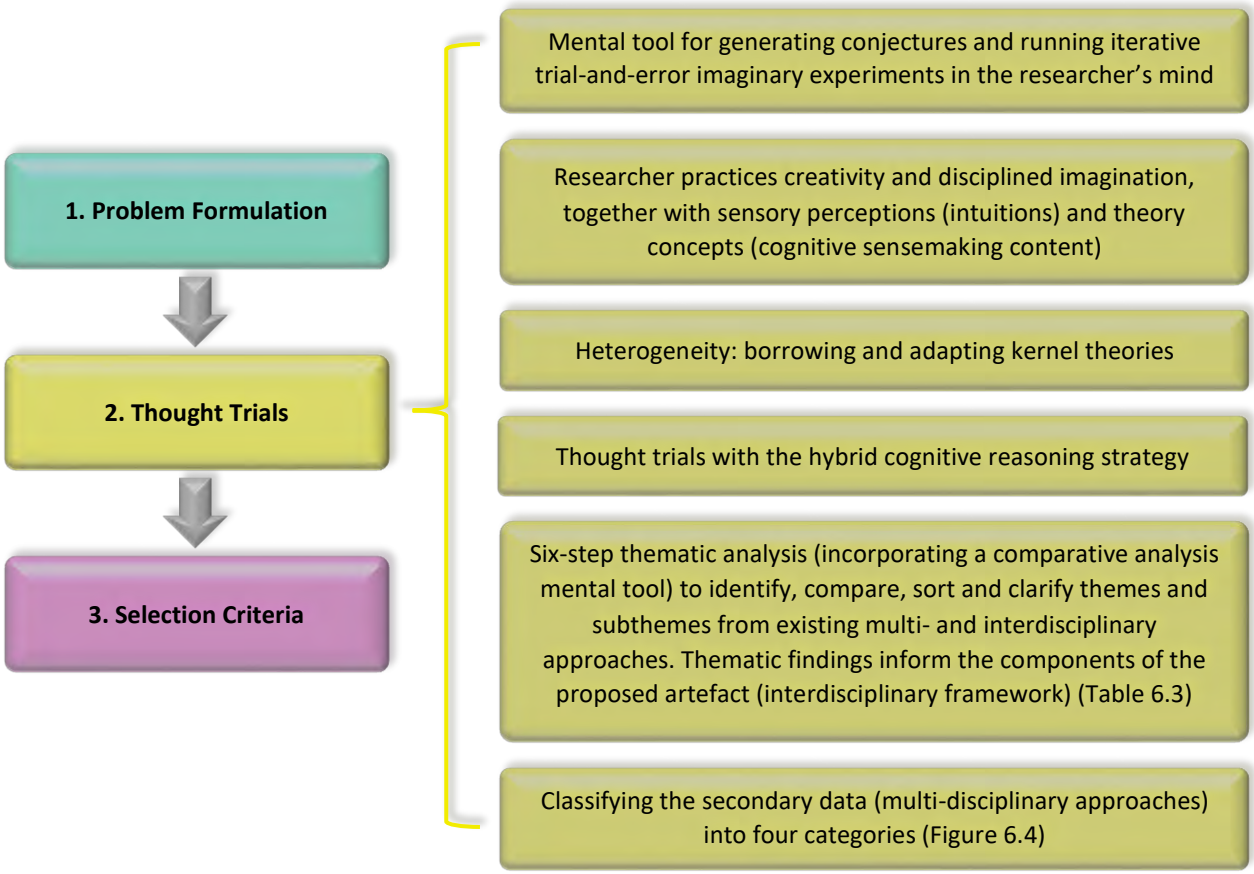



*Figure 6. 5: Weick's Theorising Approach: Thought Trials Summary*
*[Source: Researcher's own construction, informed by Weick (1989)]*

### 6.3.2.3 Selection Criteria

*Selection criteria* provide a judgement-making mental tool for determining which existing multi/interdisciplinary approaches should be included in the critical thematic and comparative theoretical analysis, and provide a template for ascertaining whether each selected approach offers sufficiently "interesting, plausible, consistent [and] appropriate" insights that can be extracted to inform the development of the proposed framework artefact (Weick, 1989, p.520). In addition, selection criteria function as a trial-and-error thought processing and pattern organising mental tool that guides the researcher's critical analysis of the selected approaches and governs how they filter and make sense of secondary data content (Weick, 1989; Truex, Holmström and Keil, 2006). To produce credible and good quality information systems DSR theory, and to ensure a trustworthy and transparent critical analysis, it is imperative that these two selection criteria and the process for searching and acquiring the secondary dataset be explicitly outlined (Baskerville and Pries-Heje, 2010; Mandviwalla, 2015). This explicit articulation also demonstrates an acknowledgement that the selection criteria (in the form of

two templates) and the secondary dataset (multi/interdisciplinary digital health intervention development approaches) are an outcome of an artificial, subjective, interpretive, critical judgement-making and hermeneutic selection process (performed by the researcher), rather than an outcome of a natural selection process (Weick, 1989).

Applying heterogeneity in the selection criteria is recommended to achieve heterogeneity in the selected product kernel theories dataset (multi/interdisciplinary approaches) (discussed in Subsection 6.3.2.2) (Weick, 1989). In interdisciplinary problem and solution environments in particular, "some of the most interesting work… happen[s] at the intersections of different disciplines", which requires the exercising of heterogeneity in selection criteria and the selected dataset, together with the practising of creativity, disciplined imagination and heterogeneity in thought trials (Weick, 1989; Schneiderhan, 2016, p.46). Moreover, when theorising and addressing complex and wicked design problems, starting with "clean slate thinking" or a "blank canvas" is cautioned against (Martinsons, Davison and Ou, 2015, p.22). Instead, using heterogeneity in selection criteria and secondary data allows the researcher to "stand on the shoulders of giants" (Martinsons, Davison and Ou, 2015, p.22) and "leverage previous work… on design properties and corresponding design theory" (Mandviwalla, 2015, p.322) as a stepping-stone for advancing theoretical conceptualisation, pattern identification and organisation, and theme/subtheme determination (Beck, Weber and Gregory, 2013).

Notably, while heterogeneity in selection criteria and the selected secondary dataset contributes significantly to the richness of theory development and strengthens the probability of constructing good quality theory and artefacts (Mandviwalla, 2015), it is imperative that the two templates and secondary dataset search and acquisition process be applied consistently throughout the critical analysis (Weick, 1989). This is to ensure that the reported thematic findings are trustworthy, credible and dependable (Weick, 1989). An inconsistent application of selection criteria and search and acquisition process can be at the expense of fragmented understanding, weak theoretical and conceptual connection building, and biased analysis outputs (Weick, 1989). This consistency is mirrored by Walsham's (2006) emphasis on criticality; that information systems theorists should remain critical particularly when undertaking research that carries interpretive and subjective sensemaking practices. Overall, consistent and critical application of the two selection criteria and the secondary dataset search and acquisition process is imperative because it "set[s] the scope" for the critical theoretical analysis and the artefact's theory development (Martinsons, Davidson and Ou, 2015, p.15).

#### 6.3.2.3.1 A Hermeneutic Approach to Secondary Data Search and Acquisition

Boell and Cecez-Kecmanovic's (2010; 2014) hermeneutic approach, which is particularised to the information systems discipline, is employed as the literature publication search and acquisition process, together with an assortment of search strategies and reading and acquisition techniques. The secondary dataset search and acquisition process is "an integrative part" of the data collection and theory building processes, and is necessary for countering cognitive overload given the vast pool of literature in the extant knowledge base (Boell and Cecez-Kecmanovic, 2014, p.270). A graphical illustration of the hermeneutic framework and search and acquisition process is provided in Boell and Cecez-Kecmanovic (2014, p.264). In comparison to the systematic literature search process, which applies a formalistic, rigid and singular method, Boell and Cecez-Kecmanovic's (2010; 2014) hermeneutic approach employs a more flexible, open-minded cyclical and iterative process. This allows the researcher to shift from a numeric-based, publication-centric approach to a topic-centric approach, which in contrast to the systematic approach, is more suitable to the critical analysis objective to acquire multi- and interdisciplinary approaches relevant for informing the novel boundary object view components of an interdisciplinary collaborative mHealth behaviour change intervention app design framework.

The hermeneutic approach also argues for a shift away from an objective, rigorous and replicable search process, towards a process that emphasises the gradual development of a secondary dataset through meaningful intellectual and critical engagement with identified and reviewed literature (Boell and Cecez-Kecmanovic, 2014). Moreover, researchers are encouraged to immerse themselves in the text over time, which through several search, acquisition and read iterations, expands their views, interpretations and understanding of the literature base, and leads to new discoveries that permits the continuous reshaping and improving of the search and acquisition process, resulting in a richer secondary dataset (Boell and Cecez-Kecmanovic, 2010). This flexible and open-minded approach is well suited to finding secondary data that intends to address a complex and wicked design problem since it allows the researcher to engage in "a reflective conversation with the situation" at hand by iteratively oscillating between the interdependent meanings of parts and the whole they form (Schön, 1983, p.95; Boell and Cecez-Kecmanovic, 2014). Furthermore, in the digital era, Boell and Cecez-Kecmanovic (2014, p.261) argue that restricting searches to a few select databases and journals no longer holds its antecedent strength in research practice and is "a risk to scholarship". This is because the knowledge base is forever growing and advancing, and for a

researcher to conduct a thorough, sufficiently complete and broadly comprehensive search and acquisition process, particularly when working in multi- and interdisciplinary spaces, publication searches should not be limited to a small number of databases or journals (Boell and Cecez-Kecmanovic, 2014).

In addition to not limiting the search to a few select databases and journals, Boell and Cecez-Kecmanovic (2014, p.264) encourage the "search and acquisition circle [cycle]" be performed several times, and suggest that searching strategies and reading and acquisition techniques be continuously improved and refined over time, resulting in a richer and more relevant dataset. From Boell and Cecez-Kecmanovic's (2014) tool collection, several search strategies and reading and acquisition techniques were selected and used during the hermeneutic secondary data search and acquisition process. Box 6.2 outlines the search strategies, namely: *key terms*; *article titles*; *authors*; *year of publication*; *databases*; *language*; *search operators*; *snowballing*; *citation analysis*; and *building blocks*. Box 6.3 outlines two reading techniques, namely *orientational reading* and *note keeping*, and one acquisition technique, namely *direct author contact*.

**Search Strategies Employed in the Hermeneutic Search and Acquisition Process**

| Strategy | Example/Description |
|---|---|
| **Key Terms** | "health intervention"; "health behaviour change intervention"; "physical activity intervention"; "approach"; "framework"; "model"; "method"; "process"; "guidelines"; "guidance"; "programme"; "design"; "development"; "evaluation"; "steps"; "phases"; "multidisciplinary"; "interdisciplinary"; "co-design"; "co-development"; "partnership"; "collaboration"; "hybrid"; "physical activity"; "mHealth"; "mobile health"; "mHealth app"; "application"; "app"; and "physical activity app". |
| **Article Titles** | Same as key terms, combined. E.g. "mHealth intervention development approach". |
| **Key Authors** | Susan Michie; Lucy Yardley; Sarah Ann Mummah; Robyn Whittaker; David C. Mohr; Artur Direito; Gerjo Kok; L. Kay Bartholomew (later L. Kay Bartholomew Eldredge); Madalina Sucala; Jonas Geuens, and more. |
| **Publication Year** | 2008-2019 (search process for critical analysis ended in late 2019) |
| **Databases** | Google Scholar; ACM Digital Library; EBSCOhost; Web of Science; ScienceDirect; Scopus; NCBI (PubMed, PMC); arXiv; Springer; APA PsycNET; Taylor & Francis Online. |
| **Language** | English |
| **Search Operators** | 'AND'; 'OR'; and 'NOT'. |
| **Citation Tracking** | Track past papers. Identifying relevant sources in reference lists of reviewed publications. |
| **Citation Analysis** | Track future papers. Identifying publications that referenced reviewed publications. |
| **Building Blocks** | Start with simple searches. Gradually rearrange, build up, refine and improve various combinations of mixed key terms over time. Suitable for the study given the lack of clear consensus terminological usage in the emerging interdisciplinary field. |

*Box 6. 2: Search Strategies Employed in the Hermeneutic Search and Acquisition Process [Source: Researcher's own construction, informed by Boell and Cecez-Kecmanovic (2010; 2014)]*

**Reading Techniques Employed in the Hermeneutic Search and Acquisition Process**

| Technique | Example/Explanation |
|---|---|
| **Orientational Reading** | Initial glances and scanning of publications to gain overall impression of: content (themes and subthemes); meeting two selection criteria templates; combination and integration of heterogeneous disciplinary knowledge and practices; main line of argument; main knowledge contribution (approaches, frameworks and processes). Method involves scanning and reading: abstracts; introductions; main headings; sub-headings; figures; tables; conclusions. |
| **Note Keeping** | Manual colour-coded note-taking throughout the iterative hermeneutic search, reading and acquisition process. Included continuous identification, sorting, refining and updating of "key terms", "article titles", "key authors", "databases", "citation tracking", "citation analysis", and "building blocks". |

**Acquisition Technique Employed in the Hermeneutic Search and Acquisition Process**

| Technique | Example/Explanation |
|---|---|
| **Direct Author Contact** | Direct author contact was made via email to authors of publications to request supplementary material that was referred to in the text but not available for download on journal article and database websites. Direct email responses were received within four working days. |

*Box 6. 3: Reading and Acquisition Techniques Employed in the Hermeneutic Search and Acquisition Process [Source: Researcher's own construction, informed by Boell and Cecez-Kecmanovic (2010; 2014)]*

Overall, several hermeneutic search and acquisition cycle iterations were performed over a ten-month period in 2019. A key challenge addressed by Boell and Cecez-Kecmanovic (2014) is the judgement call of knowing when to stop iterations and exit the hermeneutic circle. Boell and Cecez-Kecmanovic (2014) acknowledge that while an additional iteration can always be argued for, the researcher needs to make a judgement decision at some point considering that human knowledge production is an ongoing and never-ending process, and there will always be new publications available. The researcher's final decision to refrain from conducting further iterations and to exit the hermeneutic circle was based on three decision points: (1) thematic saturation; (2) time constraints; and (3) citation saturation – with all three points occurring over the duration of one week (Boell and Cecez-Kecmanovic, 2010; 2014). Firstly, thematic saturation was strongly tied to the two selection criteria templates, particularly the boundary object view based template (provided below in Table 6.5), in which case the same themes and subthemes kept emerging repeatedly. Secondly, the time constraints in terms of the methodological point of the critical theoretical analysis within the overall doctoral research project timeframe. Thirdly, citation saturation became apparent when the majority of cited publications in recently published articles referenced work the researcher had already read and was familiar with. These three cognitive judgements are recognised as valid and reasonable reasons for knowing when "enough is enough" (Boell and Cecez-Kecmanovic, 2014, p.272).

#### 6.3.2.3.2 Selection Criteria Template for Secondary Data Collection

During the hermeneutic secondary data search and acquisition process, the selected literature publications were required to meet nine criteria laid out in the first selection criteria template. As outlined in Table 6.4, these criteria included: (1) *health intervention design focus*; (2) *socioecological focus*; (3) *digital/technological focus*; (4) *evidence-based theory*; (5) *multidisciplinary, interdisciplinary and/or collaborative perspective*; (6) *main steps and activities*; (7) *sufficient detail provision*; (8) *meets template criteria (Table 6.5)*; and (9) *theory and practical example application*.

Of the nine criteria, criterion #7 was the most challenging to meet. A handful of multi- and interdisciplinary approaches that were initially considered in early hermeneutic iterations were later excluded for lacking sufficient detail provision. Examples of multi- and interdisciplinary approaches that met several selection criteria, but failed to meet criterion #7 were Johnston, et al. (2015), Biagianti, Hidalgo-Mazzei and Meyer (2017), Wilhide, Peeples and Kouyaté (2016), and Giunti (2018). Providing sufficient detail of the digital health or mHealth intervention design, development and evaluation process steps and activities, heterogeneous actors and supporting artefacts and materials was imperative to informing the development of the interdisciplinary framework artefact (Chapter 7), and therefore failing to meet criterion #7 resulted in the exclusion of several publications.

*Table 6. 4: Selection Criteria Template: Criteria for Selecting Multi- and Interdisciplinary Digital Health Intervention Development Approaches (Secondary Dataset)*
*[Source: Researcher's own construction]*

| Selection Criterion | Description |
|---|---|
| **1. Health intervention design focus** | Approach aims to guide the design, development and evaluation of health interventions; including complex health, health promotion and health behaviour change interventions. |
| **2. Socioecological focus** | Approach adopts or incorporates a socioecological perspective to health intervention design, development and evaluation. Preference for approaches orientated towards targeting the individual and interpersonal socioecological health intervention levels. |
| **3. Digital/Technological focus** | Approach is either originally developed for or has subsequently been adapted for use in guiding the design, development and evaluation of health (complex, promotion or behaviour change) interventions delivered through digital or technological platforms. Preference for digital mobile and application (app) platforms. |
| **4. Evidence-based theory** | Approach is based on or informed by evidence-based theory, theoretical frameworks, models and/or existing approaches. |
| **5. Multidisciplinary, interdisciplinary and/or collaborative** | Approach incorporates, combines and/or integrates theory, knowledge and practices from a diversity of relevant disciplines and specialisations. Preference for approaches that guide the multi- and interdisciplinary collaborative process. |

| | |
|---|---|
| **6. Main steps and activities** | Approach outlines the main process phases, stages, steps and activities to follow in the design, development and evaluation of digital health interventions. |
| **7. Sufficient detail provision** | The publication offers sufficient detail, information and insights for informing the development of the interdisciplinary framework. |
| **8. Meets template criteria (Table 6.5)** | The publication sufficiently meets the tri-composite theoretical framework (boundary object view) template criteria for informing the development of the interdisciplinary framework. |
| **9. Theory and practical example application** | The publication offers practical application examples of the theoretical approach. Preference for mobile app and physical activity behaviour change application contexts. Practical applications of an approach can be included in the original publication, or the approach may be practically applied and demonstrated in later publications. |

#### 6.3.2.3.3 Template Criteria for Conducting the Critical Theoretical Analysis

A template approach to secondary data analysis provides a preliminary set of criteria "codes" that serve as an analytic and critical lens when conducting the critical thematic and comparative theoretical analysis of the existing multi- and interdisciplinary digital health intervention development approaches (Crabtree and Miller, 1992, p.94). The template is largely informed by the tentative design suggested solution (Figure 6.1), particularly the tri-composite theoretical framework, with the intention of identifying and extracting boundary object view findings relevant for informing the development of the interdisciplinary framework artefact (Chapter 7). Notably, although the template criteria is predominantly deductive in nature, the hybrid cognitive reasoning strategy is still applied in that the researcher seeks data findings that offer satisficing design solutions (abductive processing), and remains open-minded in letting the data "speak to" them, yielding novel insights (top-down induction processing) (Lee, Pries-Heje and Baskerville, 2011; Shepherd and Sutcliffe, 2011, p.368).

When initially developed, the template criteria included twenty-four criteria. After six iterations of reviewing, adjusting and refining the template, operating through mental trial-and-error thought processing and hermeneutic meaning orientated refinement, the final revised template comprised nine criteria. As outlined in Table 6.5, these nine criteria included: (1) *multi/interdisciplinary approach number and title*; (2) *title, author and year of literature publication*; (3) *aim and summary of multi/interdisciplinary approach*; (4) *actors and community of practice members*; (5) *perspectives, underlying theories, models, tools and existing approaches*; (6) *components of multi/interdisciplinary approach*; (7) *design artefacts, boundary objects and supporting methods*; (8) *knowledge boundary contributions*; and (9) *limitations and lessons learned*. When conducting the critical theoretical analysis, all of the selected multi- and interdisciplinary digital health intervention development approaches are

critically analysed and compared in terms of each of the nine template criteria. This is imperative for the critical thematic and comparative theoretical analysis findings to inform the development of the interdisciplinary framework (Chapter 7).

*Table 6. 5: Template Criteria for Critically Analysing the Selected Multi- and Interdisciplinary Digital Health Intervention Development Approaches (Secondary Dataset) [Source: Researcher's own construction]*

| Template Criterion | Description |
|---|---|
| **1. Multi/interdisciplinary approach number and title** | The approach number (sorted 1 to 20 – Table 6.6) provides a quick reference for the researcher. The approach title succinctly labels the contribution and often indicates its perspective category (Figure 6.4), digital technology platform and health context. |
| **2. Title, author and years of literature publication** | The publication title provides information on the nature, perspective(s), category and context of the multi/interdisciplinary approach. The authors' names and year of publication offers a quick reference source. The year of publication also indicates how recent the approach contribution is, and provides insight into where knowledge and digital advancements were when published. |
| **3. Aim and summary of multi/interdisciplinary approach** | Outlines the main aim of the multi/interdisciplinary approach, in terms of purpose, intention and context focus. The summary succinctly articulates the general scope, essence and core contributory themes of the multi/interdisciplinary approach. |
| **4. Actors and community of practice members** | Identifies the boundary actors/practice community members included in the multi/ interdisciplinary team, including the knowledge brokers, project leaders and general team members. Identifies the different disciplinary backgrounds and specialisations. |
| **5. Perspectives, underlying theories, models, tools and existing approaches** | Identifies the perspectives, underlying theories, frameworks, models and tools integrated into and employed in the multi/interdisciplinary approach. Identifies if a multi/interdisciplinary approach is based on or informed by any existing approaches. |
| **6. Components of multi/ interdisciplinary approach** | Identifies the main components, themes and subthemes of the multi/interdisciplinary approach. This includes the main phases, stages, steps and activities of the design, development and evaluation process. Identifies the process nature/characteristics. |
| **7. Design artefacts, boundary objects and supporting methods** | Identifies the various collaborative design artefacts, boundary objects and supporting methods employed, utilised and produced in the multi/interdisciplinary approach. Boundary objects need to meet the three core criteria (Chapter 5, Subsection 5.3.2.5). |
| **8. Knowledge boundary contributions** | Identifies themes and subthemes relevant to the multi/interdisciplinary sharing of knowledge across knowledge boundaries. Identifies power dynamics, knowledge trade-offs and how differences, dependencies and novelties are managed/negotiated. |
| **9. Limitations and lessons learned** | Identifies noteworthy limitations or weaknesses of the multi/interdisciplinary approach. Identifies lessons learned, particularly in terms of the mobile app and physical activity behaviour change contexts. |

#### 6.3.2.3.4 Multi- and Interdisciplinary Approaches Selected for the Critical Thematic and Comparative Theoretical Analysis

Several hermeneutic cycles were performed using the search strategies, reading and acquisition techniques, and the two selection and template criteria. Hundreds of publications were reviewed and considered over a ten-month period in 2019, ultimately yielding a preliminary sample of forty-five literature publications. A lack of detail provision (selection criteria, criterion #7, Table 6.4) and an insufficient meeting of the necessary boundary object view information and insights (template criteria, Table 6.5) led to the exclusion of nine literature publications. The remaining thirty-six literature publications were carefully read, re-read, analysed and compared against the selection criteria (Table 6.4) and template criteria (Table 6.5). Appendix G.1 and Appendix G.2 provide the manual matrices created for all thirty-six publications in terms of the selection criteria and template criteria, respectively. After meticulous review, and thoughtful consideration for the four perspective categories (Figure 6.4), twenty literature publications were selected for inclusion in the final secondary dataset.

Of the twenty selected multi- and interdisciplinary approaches (literature publications), none perfectly met all nine template criteria (Table 6.5). Upon first impression, this may seem as if the hermeneutic search and acquisition approach lacked rigour; however, this is not the case. Instead, an inability to find literature publications that perfectly met all of the nine template criteria provides evidence for the knowledge gap, verifies the research project's defined problem statement, and confirms that the proposed boundary object view is in fact a novel design solution.

Of the twenty selected multi- and interdisciplinary approaches (literature publications), the number of approaches within each perspective category were: five in the Health Sciences Perspective category; seven in the Information Systems and Technology Perspective; four in the Partnership Perspective; and four in the Integrative Perspective. Important to reiterate, as emphasised in Subsection 6.3.2.2 (under the "Thematic Analysis and Thought Trial Diversity: Heterogeneity in Product Kernel Theories" sub-heading), none of the twenty selected approaches hold a singular siloed perspective; all twenty approaches incorporate a heterogeneity of disciplinary knowledge and practices, yet each approach carries a predominant perspective, informing their perspective categorisation. Moreover, on another note, not all of the selected literature publications referred to their contributions as an "approach"; some authors described their contribution as a "framework", "process", "model" or "method". The

term "approaches" is used a simple term to encapsulate all of these contribution types. In addition, not all of the selected approaches were explicitly titled by their authors as "multidisciplinary", "interdisciplinary" or "collaborative". Instead, many publications discussed the multidisciplinary, interdisciplinary and collaborative nature of their approaches in text, which further confirmed the hermeneutic search and acquisition approach as suitable for allowing the researcher to immerse themselves in the text before selecting approaches.

Table 6.6 provides a summary overview of the twenty selected multi- and interdisciplinary digital health intervention development approaches included in the secondary dataset. The approaches are classified (in no particular order) into the four perspective categories (Figure 4.6, colour coded), namely the (1) *Health Sciences Perspective*; (2) *Information Systems and Technology Perspective*; (3) *Partnership Perspective*; and (4) *Integrative Perspective*. Some approaches are accompanied by additional references (marked by an asterisk *), particularly in cases where there exists: other (generally prior) versions of the approach; online interactive toolkits of the approach; case examples of the approach applied to the mobile app and physical activity contexts; and supplementary materials were referred to in the publications' appendices.

*Table 6. 6: Summary Overview of the Twenty Selected Multi- and Interdisciplinary Digital Health Intervention Development Approaches (Secondary Dataset)*
*[Source: Researcher's own construction]*

| Category | Approach | Description |
|---|---|---|
| **Health Sciences Perspective** | **Approach #1:** Intervention Mapping (IM) Approach for Health Promotion Programmes (Bartholomew Eldredge, et al., 2016) | The approach provides developers of health promotion interventions with a systematic framework for effective decision making over six steps. Each step comprises several tasks, which upon completion, results in artefacts for guiding the subsequent step. The final product outlines a theoretical, empirical and practical blueprint detailing components, themes and subthemes for the intervention's development. The IM Approach has been applied to different generic, technological and mHealth intervention contexts. |
| | ** Prior IM Versions (Bartholomew, et al., 1998; Bartholomew, et al., 2011)*<br>** Case Application for mHealth Physical Activity Behaviour Change 'Active Coach' App (Simons, et al., 2018)* | |
| | **Approach #2:** Holistic Approach to eHealth Technology Development: The CeHRes Roadmap (Van Gemert-Pijnen, et al., 2011) | The approach provides multidisciplinary developers with a participatory development process and practical guidelines for co-creating and coordinating the development, implementation and evaluation of eHealth technologies. It outlines five intertwined phases and connecting cycles, and artefact outputs for each phase. It is based on an analysis of sixteen existing eHealth frameworks. It integrates evidence-based models from persuasive technology, human-centred design, participatory development and business modelling. The approach provides valuable insights for the collaborative and shared co-production of eHealth technology products, and supports decision-making in eHealth development. |
| | ** The Online CeHRes Roadmap Toolkit (Van Gemert-Pijnen, et al., 2019)* | |
| | **Approach #3:** MRC Guidance for Developing, Evaluating and Implementing | The approach provides guidelines for conducting an iterative, non-linear and non-cyclical process for developing, evaluating and implementing complex health interventions. It outlines four main stages (comprising three |

| | | |
|---|---|---|
| | Complex Health Interventions (Craig, et al., 2008)<br>** Updated MRC Guidance (Shahsavari, et al., 2020)* | activities each) along with standard questions for guiding developers in recognising and adopting appropriate methods for each stage. The approach provides key themes, methods and modelling artefacts applicable for the development and evaluation of theory and evidence-based health behaviour change interventions. |
| | **Approach #4:**<br>Six Steps for Quality Health Intervention Development (6SQuID) (Wight, et al., 2015)<br>** Case Application for mHealth Physical Activity Behaviour Change 'HelpMeDot!' App (Matthews, et al., 2017)* | The approach offers a systematic and pragmatic six-step method for guiding the design of quality public health interventions. Steps provide questions and recommended artefacts for logical and practical intervention development. 6SQuID is applied to interventions for gender-based violence, but details themes applicable to a wider variety of health contexts, and has been used for guiding mHealth physical activity behaviour change intervention app development. |
| | **Approach #5:**<br>Intervention Mapping and the Behavioural Intervention Technology Framework for Developing a mHealth Physical Activity and Sedentary Behaviour Change App (Direito, et al., 2018)<br>** Supplementary Material for the mHealth Physical Activity Behaviour Change 'TODAY' App (Direito, et al., 2018)* | The publication integrates the Intervention Mapping (IM) approach (Approach #1) and the Behavioural Intervention Technology (BIT) model (Approach #7), to develop an adaptive mHealth promotion intervention app targeting physical activity and sedentary behaviour change at the dual intra-interpersonal socioecological level. It outlines key themes and subthemes relevant to the theoretical and evidence-based design of physical activity intervention apps. Together with supplementary material, the paper provides extensive detail on linking, translating and operationalising physical activity health behaviour change theory and behaviour change techniques to the mobile app platform. |
| **Information Systems and Technology Perspective** | **Approach #6:**<br>Development and Evaluation Process for mHealth Interventions (Whittaker, et al., 2012)<br>** Case Application for mHealth Physical Activity Behaviour Change 'Active Coach' App (Simons, et al., 2018)* | The approach outlines six steps for developing, pre-testing and evaluating mHealth interventions. Three crosscutting themes underlie the process, including a focus on target audience involvement, an underpinning theoretical basis, and a focus on mobile platform implementation. The publication's case application provides insights on methods, questions and measures at each step of the process. The approach has been applied in different mHealth behaviour change intervention app development contexts, including physical activity. |
| | **Approach #7:**<br>The Behavioural Intervention Technology (BIT) Model for eHealth and mHealth Interventions (Mohr, et al., 2014)<br>** Supplementary Material for mHealth Physical Activity and Dietary Behaviour Change MyFitnessPal App (Mohr, et al., 2014)*<br>** Case Applications to two mHealth Physical Activity Behaviour Change Apps: 'HelpMeDot!' (Matthews, et al., 2017) and 'TODAY' (Direito, et al., 2018)* | The model provides a conceptual framework for articulating and translating the relationships between intervention aims, elements, characteristics and workflow. The model also includes a technological framework (BIT-Tech) for operationalising and instantiating the conceptual framework for technical implementation. It offers guidance to multi/interdisciplinary intervention teams by bridging the different fields and perspectives of health behavioural intervention sciences, health psychology, technology, information systems design and software engineering. The BIT model outlines key themes and subthemes for mHealth physical activity intervention app development. The model has been applied to different mHealth behaviour change intervention app contexts, including physical activity. |
| | **Approach #8:**<br>IDEAS (Integrate, DEsign, Assess and Share) Framework and Toolkit for Digital Health Behaviour Change Intervention Development (Mummah, et al., 2016)<br>** Case Application for mHealth Physical Behaviour Change 'Puzzle Walk' App (Lee, et al., 2018b)* | IDEAS provides a framework and toolkit for guiding multi/interdisciplinary teams in the design, development and evaluation of digital health behaviour change interventions. The framework outlines ten phases grouped into four stages. The publication identifies themes and artefacts at each phase for supporting teams during collaborative multi/interdisciplinary engagement and development, and outlines pragmatic guidance for applying the framework. IDEAS has been applied to different mHealth promotion behavioural change intervention app contexts, including physical activity. |
| | **Approach #9:**<br>mHealth App Intervention Development Process (Curtis, Lahiri and Brown, 2015) | The approach outlines an iterative process for developing theory and evidence-based mHealth behaviour change intervention apps. It comprises ten steps, grouped into three stages, and identifies artefacts for collaborative intervention design and development. The publication discusses and applies key themes and subthemes relevant to the multi/interdisciplinary design, development and evaluation of mHealth physical activity behaviour change intervention apps. |

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| | **Approach #10:** Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps (Geuens, et al., 2019a)<br>** First Version (Geuens, et al., 2016)*<br>** The Online Lenses of Motivational Design for mHealth Toolkit (Geuens, et al., 2019b)* | The dyadic lenses aim to provide app designers and health researchers with actionable advice for translating and operationalising psychological and health theories into mHealth behaviour change intervention app design features. It bridges the two disciplinary gaps by providing cross-links between theory and implementation. Descriptions, guiding questions, practical examples, graphical explanations, graphical screenshot examples from real-world mHealth physical activity apps, and additional references are provided. The dyad integrates themes and frameworks from fields of persuasive technology and systems design, mobile app design, health psychology, and health behaviour change intervention development. The dyadic lenses for motivational design are particularised to the dual intra-interpersonal socioecological levels of health promotion, and have been applied to the mHealth physical activity behaviour change intervention app context. |
| | **Approach #11:** mHealth Intervention Design Process for Behaviour Change (Smith, et al., 2016) | The process provides systematic and comprehensive guidance for designing mHealth behaviour change interventions over four stages. It is built on an integration of Whittaker, et al.'s (2012) process (Approach #6), a model of user-centred design, and three theoretical frameworks of health behaviour change. It outlines themes, subthemes and artefacts applicable to the mHealth physical activity intervention app context. |
| | **Approach #12:** Agile Development and Evaluation Approach for mHealth Apps (Wilson, et al., 2018) | The approach offers an agile, iterative and rapid lifecycle for designing, developing and evaluating mHealth apps. It consists of a project identification phase followed by four phases of clinical development, and includes gating questions for each phase. The approach integrates themes and models from information systems, software design engineering, user-centred design, user experience design, clinical trial testing, and commercial app and marketing research. It suggests using iterative A/B testing prior to clinical trial evaluation. The publication applies the approach to the pharmaceutical mHealth app context, but it is generic enough to provide insights and lessons learned for the mHealth physical activity behaviour change intervention app context. |
| **Partnership Perspective** | **Approach #13:** The Person-Based Approach for Developing Digital Health Behaviour Change Interventions (Yardley, et al., 2015a)<br>** Case Application for mHealth Physical Activity Behaviour Change 'HelpMeDot!' App (Matthews, et al., 2017)* | The approach aims to guide the development of digital health behaviour change interventions by focusing on understanding and accommodating the psychosocial contexts and user experience perspectives of people who will use them. It outlines two key parts for achieving this: conducting in-depth qualitative research, and producing guiding principles. This approach provides themes primarily from a health psychology and health behavioural sciences perspective, rather than a technological perspective, but can be integrated with the user-centred design process and used complementarily alongside other theory and evidence-based approaches. The approach has been employed and applied in the mHealth physical activity behaviour change intervention app context. |
| | **Approach #14:** Participatory Design Approach for Stakeholder Engagement in Quality Health Behaviour Change Intervention Development (Carvalho, Jun and Mitchell, 2017) | The approach emphasises a participatory process for the collaborative co-development of health behaviour change interventions. It outlines three main components, and identifies theory and evidence-based artefacts (methods and tools) that foster stakeholder engagement within each stage. The publication applies the approach to a medical emergency department and urinary tract infection context, but provides themes, insights and lessons learned applicable to the multi/interdisciplinary collaborative and participatory design of mHealth physical activity behaviour change intervention apps. |
| | **Approach #15:** Co-Design Approach for Developing Tailored mHealth Behaviour Change Intervention Apps (Verbiest, et al., 2018) | The approach integrates six steps of participatory co-design with four steps for mHealth behaviour change intervention app design, and incorporates an evidence-based theoretical health behavioural change framework. It emphasises themes on the participatory involvement of target users for developing a tailored, culturally appropriate healthy lifestyle management app. The publication describes links between health behavioural change determinants, intervention components, and mHealth app design features. The approach is applicable to different mHealth behaviour change intervention app contexts, including physical activity. |

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| | **Approach #16:** Multi-Disciplinary Thematic Seminars as a Collaborative Design Method for Health Information Systems Development (Scandurra, Hägglund and Koch, 2008a)<br>** Two Case Applications (Scandurra, Hägglund and Koch, 2008b)* | MdTS uses thematic seminars as a collaborative tool for eliciting user needs from different perspectives, and aims to identify points of intersection to establish a common ground for cooperative multi/interdisciplinary work. It details themes on shared understanding, cooperative work processes and practices, joint activity workflows, interpretive flexibility, shared artefacts and communication tools. The MdTS method is based on methods of participatory design, user-centred systems design, human-centred design, and computer supported cooperative work. Although applied to the healthcare information systems context, it provides valuable insights for multi/interdisciplinary teams designing mHealth physical activity behaviour change intervention apps. |
| **Integrative Perspective** | **Approach #17:** Holistic Framework for Developing Digital Health Behaviour Change Interventions: TUDER (Wang, et al., 2019)<br>** First Version (Wang, et al., 2017)*<br>** Supplementary Material for the TUDER integrative taxonomy (Wang, et al., 2019)* | The framework provides an iterative, comprehensive process and two integrated taxonomies for designing, developing and evaluating digital health behavioural change interventions. It consists of four steps, two toolboxes, a workflow and a checklist. TUDER is based on existing approaches [CeHRes Roadmap (Approach #2), BIT Model (Approach #7), IDEAS (Approach #8), and the PSDM (Chapter 4)], and integrates models from different fields including health behavioural intervention sciences, health psychology, persuasive technology, information systems, digital health technology and just-in-time adaptive intervention technology. It details themes and subthemes on multi/interdisciplinary knowledge integration, methods and artefacts. The first version (*2017) details valuable themes and insights particularised and applied to the context of mHealth physical activity behaviour change intervention apps. |
| | **Approach #18:** Multidisciplinary Approach for the Agile Development of Gamified mHealth Behaviour Change Intervention Apps (Edwards, et al., 2018) | The approach offers a collaborative and iterative seven-step process for developing theory informed and evidence-based gamified mHealth behaviour change apps. It emphasises an expert multidisciplinary design team theme during the development process. The integrative approach incorporates an existing approach [MRC Guidelines (Approach #3)], and combines themes and models from fields of health psychology, health behavioural change intervention sciences, information systems design, engineering, computer science, gamification and game development, and user experience design. The publication's case application is to a mHealth smoking cessation app, but the approach is applicable to other mHealth behavioural change intervention app contexts, including physical activity. |
| | **Approach #19:** Multidisciplinary Approach for Developing Health Promotion Behaviour Change Intervention Persuasive Technology (Blanson Henkemans, et al., 2015) | The multidisciplinary approach aims to support the iterative development of health promotion behaviour change interventions by integrating frameworks from fields of psychology, behavioural and social sciences, cognitive engineering, human factors, persuasive technology, human computer interaction, and information systems design. It is based on two existing approaches [IM (Approach #1), Situated Cognitive Engineering], and comprises three components covering themes that integrate technological features and health behaviour change strategies. It aims to provide multidisciplinary teams with practical guidance for bridging language gaps and barriers between different disciplines. It details themes on collaborative communication and design artefacts, methods, interpretive flexibility and sound design rationales. The approach can be applied to different contexts, including mHealth physical activity intervention apps. |
| | **Approach #20:** Behavioural Science-Informed User Experience Design (BSUED) Process for mHealth Behaviour Change Intervention Apps (Hekler, et al., 2011)<br>** Supplementary Material (Hekler, et al., 2011)*<br>** Case Applications to Three mHealth Physical Activity Behaviour Change Intervention Apps (King, et al., 2013; 2016)* | BSUED provides an approach that integrates evidence-based health behavioural science theory and user experience design into a process for developing commercial mHealth behaviour change apps. It aims to articulate motivational frames as drivers for intervention designs, and offers a design thinking approach to the iterative testing process. Supplementary material provides insights into the main artefact supporting cross-disciplinary motivational frame conception. BSUED has been applied in developing and testing three motivationally framed mHealth physical activity behaviour change intervention apps. Themes and subthemes detail links and translations of intervention components into app design features. |

***Selection Criteria Summary***

In short, Section 6.3.2.3 has described the third component of Weick's (1989) theorising approach, and has elaborated on the components constituting the selection criteria. The hermeneutic search and acquisition approach applied to collect the secondary dataset (multi- and interdisciplinary digital health intervention development approaches), and the two selection and template criteria used to identify and select approaches were outlined, and a summary overview of the twenty selected approaches was provided. This methodological and transparent process gives credibility to the critical analysis and theorising process. Figure 6.6 summarises the key points of the thought trials in this critical analysis.

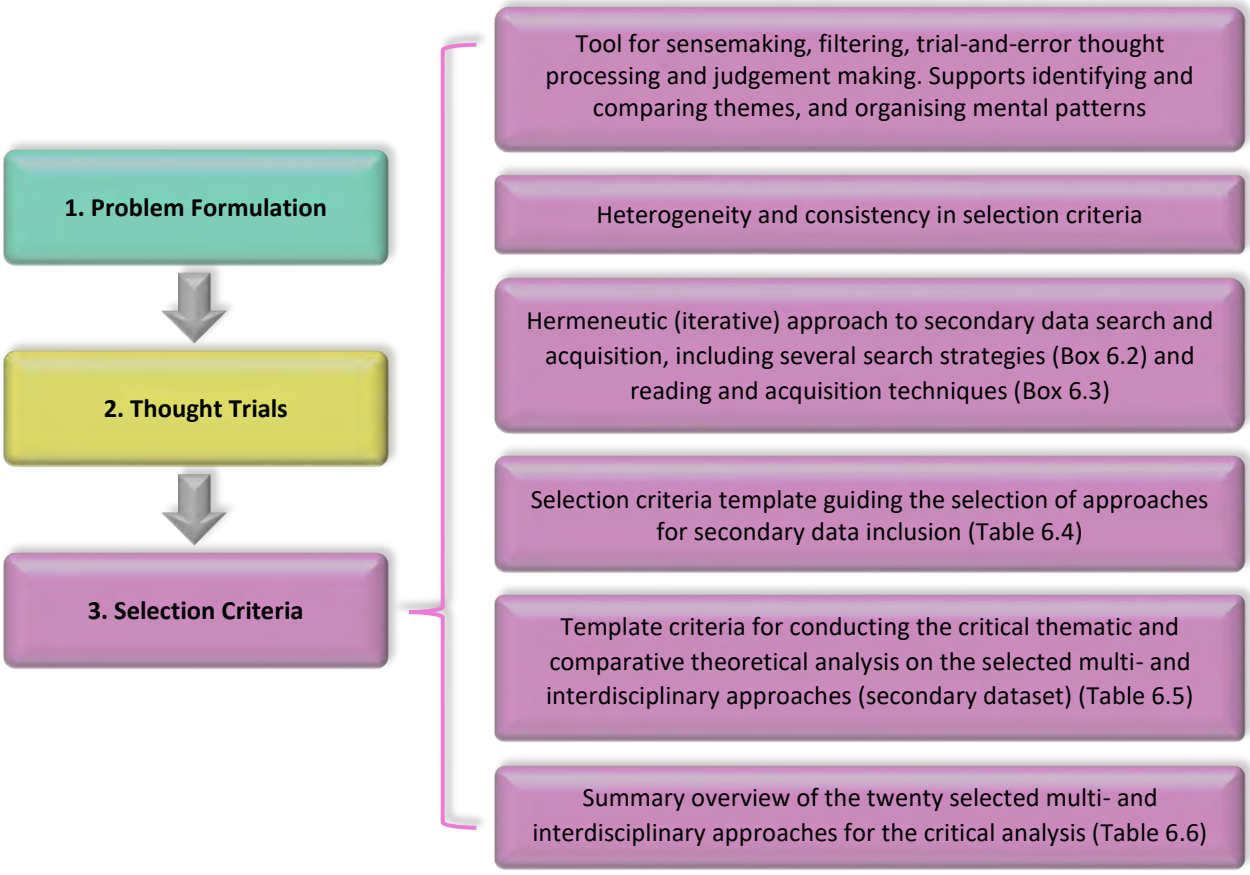



*Figure 6. 6: Weick's Theorising Approach: Selection Criteria Summary*
*[Source: Researcher's own construction, informed by Weick (1989)]*

## 6.4 Critical Theoretical Analysis of Multi- and Interdisciplinary Approaches

The template criteria (Table 6.5) provides a lens for conducting the critical thematic and comparative theoretical analysis on the twenty selected multi- and interdisciplinary digital health intervention development approaches (Table 6.6) across the four perspective categories (Figure 6.4). The hybrid cognitive reasoning strategy, along with disciplined imagination, thought trials, sensory perceptions, cognitive sensemaking, creativity, plausibility judgements and trial-and-error imaginary (mental) experimentation, is applied to identify, critically analyse and organise themes and subthemes relevant to the proposed boundary object view and intended interdisciplinary framework artefact (Chapter 7).

To conduct the critical thematic and comparative theoretical analysis, the six-step process was applied (Table 6.3). To briefly describe the key aspects of the process, firstly, the twenty selected multi- and interdisciplinary approaches were carefully read and re-read, and colour-coded highlights and notes were made, to enhance the researcher's familiarity with each literature publication and approach contribution. Secondly, the researcher meticulously reviewed, summarised and critically analysed each multi- and interdisciplinary approach according to the nine criteria in the template (Table 6.5). Four detailed A3 tables spanning 75 pages, organised by perspective category (Tables A, B, C and D, respectively), were produced during this meticulous process (Appendix H). Thereafter (thirdly), the researcher deeply immersed themselves in Appendix H, and performed critical cross comparisons of all potential themes, subthemes and theme relationships for the approaches within each of the four categories. The findings were then written up and reported in Sections 6.4.1 to 6.4.4.

Sections 6.4.1 to 6.4.4 provide the critical thematic and comparative theoretical analysis findings on the multi- and interdisciplinary approaches. The findings are divided in accordance with the four categories, namely the *Health Sciences*, *Information Systems and Technology*, *Partnership*, and *Integrative* perspectives, respectively. The findings are presented and discussed in terms of seven main themes (seven sub-headings), based on the template criteria (Table 6.5). The seven main themes cover the: (1) *aims and contexts*; (2) *actors and community of practice members*; (3) *perspectives, underlying theories, models, tools and existing approaches*; (4) *nature of the approaches and process steps and activities*; (5) *any design artefacts, boundary objects and supporting methods employed at each process step*; (6) *knowledge boundary contributions*; and (7) *noteworthy limitations and lessons learned*.

### 6.4.1 A Critical Analysis of Multi- and Interdisciplinary Approaches: A Health Sciences Perspective

Multi- and interdisciplinary approaches offering a predominant health sciences perspective are imperative to review and critically analyse because they provide insight into the health context, particularly the health promotion and health behaviour change intervention landscapes, which informs the foundation for designing, developing and evaluating digital health interventions. The Health Sciences Perspective category specifically consists of approaches intended for: general health promotion interventions and programmes (Approach #1); generic health information systems such as eHealth systems and technologies (Approach #2); general complex health interventions (Approach #3); general public health interventions (Approach #4); and digital health behavioural change interventions targeting physical activity in particular (Approach #5). Overall, the five health sciences approaches provide insight into the main themes and subthemes that are essential and fundamental to the health intervention context.

The template criteria (Table 6.5) is used to critically analyse each of the five approaches. Table A in Appendix H provides a full detailed summary analysis of the health science approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the five approaches, presented in a written report discussion. Box 6.4 identifies the five multi- and interdisciplinary approaches classified in the Health Sciences Perspective.

- **Approach #1** The Intervention Mapping (IM) Approach for Health Promotion Programmes
- **Approach #2** The Holistic Approach to eHealth Technology Development: The CeHRes Roadmap
- **Approach #3** MCR Guidance for Developing, Evaluating and Implementing Complex Health Interventions
- **Approach #4** Six Steps for Quality Health Intervention Development (6SQuID)
- **Approach #5** IM and the BIT Framework for Developing a mHealth Physical Activity and Sedentary Behaviour Change App

*Box 6. 4: Multi- and Interdisciplinary Approaches: Health Science Perspective [Source: Researcher's own construction]*

#### 6.4.1.1 Aims and Contexts of Health Science Perspective Approaches

The five multi- and interdisciplinary approaches categorised in the Health Sciences Perspective share a common aim: *to guide intervention designers and developers through a process,*

*comprising a series of steps (also referred to as stages, phases or components), that ultimately yields the production of health interventions that are either generic (non-technological) or systems-/digitally-based (technological)*. Approaches #1, #3 and #4 aim to provide a process for developing health interventions in general, intended for delivery through various modes and platforms. Approaches #2 and #5, in comparison, aim to provide a process for developing health interventions delivered through digital and technological platforms. Out of the five approaches, only Approach #5 is aimed at guiding the design of behaviour change interventions intended for delivery via mobile devices and apps in particular. Moreover, Approach #5 is the only approach in the critical analysis that specifically targets physical activity behaviour change. Notably though, the other four approaches (#1, #2, #3 and #4) have been employed, adapted and applied to both the mHealth app and physical activity behaviour change intervention contexts in a range of studies; for example, Brug, Oenema and Ferreira (2005), Matthews, et al. (2017), Middelweerd, et al. (2018) and Simons, et al. (2018).

In terms of target audience, all five approaches have been employed for informing the design, development and evaluation of health interventions across one or more socioecological levels of health promotion and NCD prevention, and have been used specifically for targeting the individual and interpersonal socioecological levels. Overall, all five of the approaches aim to support multi- and interdisciplinary collaborative team involvement, provide theory and evidence-based processes, and rely on methods, artefacts and objects to support teams' collaborative efforts. Furthermore, all five approaches aim to harness and/or draw from existing theoretical models, although only three of the five approaches (Approaches #3, #4 and #5) aim to provide health intervention development guidance based on existing approaches. Approach #5, for instance, is based on an integration of *Intervention Mapping* and *The Behavioural Intervention Technology (BIT) Model*, namely Approaches #1 and #7, respectively.

For purposes of length, the Health Sciences Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.1.2 to 6.4.1.7 are extracted to Appendix I. One summary table and two summary figures for the Health Sciences Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

### 6.4.2 A Critical Analysis of Multi- and Interdisciplinary Approaches: An Information Systems and Technology Perspective

Multi- and interdisciplinary approaches offering a predominant information systems and technological perspective are of paramount importance to review and critically analyse,

especially considering their knowledge contribution to understanding the digital technology platforms through which health (promotion) behaviour change interventions are delivered. Put simply, they provide insight into the mode of intervention delivery. Multi- and interdisciplinary approaches focusing on mobile devices and apps in particular are instrumental to informing the development of the interdisciplinary framework artefact (Chapter 7). Reviewing these approaches provides insight into the various ways health behavioural change interventions can be designed, developed, evaluated and delivered digitally by multi/interdisciplinary collaborating teams. Reviewing these approaches provides further understanding of the general strengths, challenges and limitations associated with delivering health interventions via digital technology platforms. The Information Systems and Technology Perspective category specifically covers approaches intended to support the design, development and evaluation of: digital health interventions, eHealth interventions and complex digital health interventions (Approaches #7 and #8); mHealth and mHealth app interventions (Approaches #6, #7, #9, #10, #11 and #12); and persuasive technology/systems and health behavioural change support systems (Approaches #7 and #10). Overall, the seven information systems and technology approaches provide insight into the main themes and subthemes that are necessary and relevant to the mHealth behaviour change intervention app design, development and evaluation context.

The template criteria (Table 6.5) is used to critically analyse each of the seven approaches. Table B in Appendix H provides a full detailed summary analysis of the information systems and technology approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the seven approaches, presented in a written report discussion. Box 6.5 identifies the five multi- and interdisciplinary approaches classified in the Information Systems and Technology Perspective.

- **Approach #6** Development and Evaluation Process for mHealth Interventions
- **Approach #7** The Behavioural Intervention Technology (BIT) Model for eHealth and mHealth Interventions
- **Approach #8** IDEAS (Integrate, DEsign, Assess and Share) Framework and Toolkit for Digital Health Behaviour Change Intervention Development
- **Approach #9** mHealth App Intervention Development Process
- **Approach #10** Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps
- **Approach #11** mHealth Intervention Design Process for Behaviour Change
- **Approach #12** Agile Development and Evaluation Approach for mHealth Apps

*Box 6. 5: Multi- and Interdisciplinary Approaches: Information Systems and Technology Perspective [Source: Researcher's own construction]*

#### 6.4.2.1 Aims and Contexts of Information Systems and Technology Perspective Approaches

The seven multi- and interdisciplinary approaches categorised in the Information Systems and Technology Perspective share a common aim: *to guide designers and developers through a process, comprising a series of steps and activities, that ultimately leads to the development and release of a technology-based health intervention*. Six of the seven approaches, namely Approaches #6, #7, #9, #10, #11 and #12, aim to guide the design and development of mHealth intervention apps specifically. Approach #7 provides a design and development process for both mHealth and eHealth interventions. Approach #8, in comparison, aims to guide the design and development of health behaviour change interventions for digital technologies overall, although Mammah, et al. (2016) explain that this includes mHealth intervention apps together with eHealth and other digital technologies.

Five of the seven approaches (with the exceptions of Approaches #9 and #12) have been applied to the physical activity health (promotion) behaviour change context. Several studies have employed these multi- and interdisciplinary approaches when designing, developing and evaluating physical activity behaviour change intervention apps in particular. Example apps include, namely: *MyFitnessPal* (Mohr, et al., 2014), *HelpMeDot!* (Matthews, et al., 2017) and *TODAY* (Direito, et al., 2018), which all used Approach #7; *Puzzle Walk* (Lee, et al., 2018b), which used Approach #8; and *30 Day Fitness Challenge*, *Step Counter*, *Nike+ Running*, *Fitocracy* and *Endomondo* (Geuens, et al., 2016; 2019a, 2019b), which were all examined using Approach #10. The two exceptions, Approaches #9 and #12, when first developed, were aimed at targeting the healthy lifestyle and pharmaceutical mHealth app contexts, respectively. Notably, Approach #9 is aimed at the healthy lifestyle context in general, targeting physical activity together with healthy eating, hygiene and smoking cessation. Approach #9, when originally developed, was used for the creation and evaluation of the *Health Heroes* app, which has subsequently been released on the public Android Google Play and Apple iOS consumer app stores. In contrast to the other six approaches, Approach #12 was first developed and applied in the clinical pharmaceutical mHealth app context, although lessons learned from the approach offer generic contributions valuable to the mHealth physical activity behaviour change intervention app context.

With regard to target audience, all seven approaches have been employed and used for informing the design, development and evaluation of mHealth intervention apps aimed at the

dual intra-interpersonal socioecological intervention levels. Overall, all of the seven approaches aim to support multi- and interdisciplinary collaborative team efforts, include theory and evidence-based processes, and describe using methods, artefacts and objects to facilitate and mediate collaborating team's efforts. Furthermore, all seven approaches harness and/or draw from existing theoretical models, and five of the seven approaches (with the exceptions of Approaches #7 and #10) aim to provide digital health and mHealth intervention development process guidance based on existing multi/interdisciplinary approaches. Approaches #6 and #9, for instance, are developed by incorporating components and themes from *Intervention Mapping* (Approach #1). Notably, Approach #8 reviews and/or draws from seven existing process approaches, including Approaches #2, #3, #6, #13 and #20.

For purposes of length, the Information Systems and Technology Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.2.2 to 6.4.2.7 are extracted to Appendix I. One summary table and two summary figures for the Information Systems and Technology Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

### 6.4.3 A Critical Analysis of Multi- and Interdisciplinary Approaches: A Partnership Perspective

Multi- and interdisciplinary approaches that offer a predominant partnership perspective are important to review because they provide insight into the ways digital health behaviour change interventions, and apps in particular, can be designed, developed and evaluated through active collaboration and participatory efforts. By collaboratively engaging with heterogeneous practice communities in the project team, a variety of knowledge, expertise, skills and practices, as well as different perspectives, opinions and suggestions can be contributed towards improving the output design solution and effectiveness potential of an mHealth app product. Other collaborative, participatory and partnership efforts can involve end users (as representatives of the target population) and external third party stakeholders (such as mobile app development consulting companies, cultural experts and business managers). The Partnership Perspective category includes a review of approaches that emphasise: the co-design, co-creation, co-development, co-production, co-evaluation and co-implementation of health interventions (Approaches #14 and #15); the participatory design of health behaviour change interventions (Approach #14); a user-centred/target audience-based approach to digital health behaviour change intervention development (Approaches #14, #15 and #16); and a

person/human-centred approach to digital health behaviour change intervention development (Approach #13). Overall, all four approaches provide insight into collaborative, participatory and partnership themes and subthemes that are valuable to the multi- and interdisciplinary mHealth physical activity behaviour change intervention app design, development and evaluation process.

The template criteria (Table 6.5) is used to critically analyse each of the four approaches. Table C in Appendix H provides a full detailed summary analysis of the partnership approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the four approaches, presented in a written report discussion. Box 6.6 identifies the four multi- and interdisciplinary approaches classified in the Partnership Perspective.

- **Approach #13** The Person-Based Approach for Developing Digital Health Behaviour Change Interventions
- **Approach #14** Participatory Design Approach for Stakeholder Engagement in Quality Health Behaviour Change Intervention Development
- **Approach #15** Co-Design Approach for Developing Tailored mHealth Behaviour Change Intervention Apps
- **Approach #16** Multidisciplinary Thematic Seminars as a Collaborative Design Method for Health Information Systems Development

*Box 6. 6: Multi- and Interdisciplinary Approaches: Partnership Perspective*
*[Source: Researcher's own construction]*

### 6.4.3.1 Aims and Contexts of Partnership Perspective Approaches

The four multi- and interdisciplinary approaches categorised in the Partnership Perspective share a common aim: *to involve, accommodate and engage collaborative and participatory contributions throughout the design, development and evaluation process, ultimately leading to the production of a collaborative technology-based health intervention*. All four approaches aim to provide guidance by employing and adapting collaborative and/or participatory methods and techniques borrowed from qualitative research as well as human-centred, user-centred and/or user experience design approaches. Approach #13 aims to guide the development of digital health behaviour change interventions by using in-depth qualitative research methods that focus on ascertaining, understanding and accommodating the psychosocial contexts and user experience perspectives of the target population. Approaches #14 and #15 aim to incorporate collaborative and participatory design methods that emphasise the co-design, co-

development, co-evaluation and co-implementation of health behaviour change interventions, with various interested stakeholders and target end user representatives. Approach #16 aims to provide guidance for the collaborative design and development of health information systems by involving various stakeholders and end user representatives in a cooperative multi-disciplinary work environment.

Approach #13 aims to guide the development of digital health behaviour change interventions in general, including mHealth apps. Approach #15, in comparison, is aimed at the mHealth app platform specifically, while Approach #16 is aimed at guiding the collaborative development of health information systems, and not mHealth intervention apps specifically. In contrast to these three approaches, Approach #14 aims to provide a participatory design approach for developing "quality" health behaviour change interventions in general, regardless of whether they are intended for delivery via digital technology platforms or not (Carvalho, Jun and Mitchel, 2017, p.7). Furthermore, on the one hand, two of the four approaches, namely Approaches #13 and #15, have been used to target physical activity behaviour change in particular. For example, Approach #13 and Approach #15 were used to guide the development of the *HelpMeDot!* (Matthews, et al., 2017) and *OL@-OR@* (Verbiest, et al., 2018) physical activity apps, respectively. On the other hand, Approaches #14 and #16 were developed to target the medical and healthcare contexts, although notably, both can provide valuable insights and lessons learned for the collaborative and participatory design, development and evaluation of mHealth physical activity behaviour change intervention apps.

In terms of target audience, Approaches #13 and #15 have been applied to the individual and interpersonal socioecological levels of health promotion, and Approaches #14 and #16 have been applied to the organisational socioecological level. Overall, all four of the approaches aim to provide multi- and interdisciplinary guidance by stressing collaborative, cooperative and participatory team involvement and discuss the use of methods, artefacts and objects to support collaborative partnership efforts. Only two of the four approaches (Approaches #13 and #14), however, review and/or draw from existing approaches, including *Intervention Mapping* (Approach #1) and *The MRC Guidance for Developing, Evaluating and Implementing Complex Health Interventions* (Approach #3).

For purposes of length, the Partnership Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.3.2 to 6.4.3.7 are extracted to Appendix I.

One summary table and two summary figures for the Partnership Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

### 6.4.4 A Critical Analysis of Multi- and Interdisciplinary Approaches: An Integrative Perspective

Multi- and interdisciplinary approaches that offer a predominant integrative perspective are pertinent to analyse because they contribute multi- and interdisciplinary viewpoints that consolidate and amalgamate knowledge from different disciplines/specialisations and different worldview perspectives. Integrative approaches are valuable in that they seek ways of bridging the divides between heterogeneous communities of practice, all of which contribute necessary and relevant knowledge, expertise, skills and practices to the collaborative design, development and evaluation of mHealth behaviour change intervention apps. The Integrative Perspective category covers approaches to digital and mHealth behaviour change intervention app design, development and evaluation that are described as: holistic (Approach #17); multidisciplinary (Approaches #18 and #19), interdisciplinary (Approach #20); and integrative (Approaches #17, #19 and #20). Overall, the four approaches provide insight into the integrative main themes and subthemes that are relevant and valuable to the multi- and interdisciplinary mHealth physical activity behaviour change intervention app design, development and evaluation process.

The template criteria (Table 6.5) is used to critically analyse each of the four approaches. Table D in Appendix H provides a full detailed summary analysis of the integrative approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the four approaches, presented in a written report discussion. Box 6.7 identifies the four multi- and interdisciplinary approaches classified in the Integrative Perspective.

- **Approach #17** Holistic Framework for Developing Digital Health Behaviour Change Interventions: TUDER
- **Approach #18** A Multidisciplinary Approach for the Agile Development of Gamified mHealth Behaviour Change Intervention Apps
- **Approach #19** A Multidisciplinary Approach for Developing Health Behaviour Change Intervention Persuasive Technology
- **Approach #20** Behavioural Science-Informed User Experience Design (BSUED) Process for mHealth Behaviour Change Intervention Apps

*Box 6. 7: Multi- and Interdisciplinary Approaches: Integrative Perspective*
*[Source: Researcher's own construction]*

#### 6.4.4.1 Aims and Contexts of Integrative Perspective Approaches

The four multi- and interdisciplinary approaches categorised in the Integrative Perspective share a common aim, which Crutzen (2014, p.1) succinctly describes as the intention *to combine and join "the best of both [or more] worlds"*. In other words, the integrative approaches share a common aim: *to bridge the divides between independently established, albeit intersecting, heterogeneous practice communities, and consolidate and fuse knowledge from different disciplines/specialisations and different worldview perspectives, in order to produce better designed and more effective mHealth behaviour change intervention apps.* Furthermore, at each stage of the collaborative process, integrative approaches aim to support and facilitate multi- and interdisciplinary communication, collaboration and cooperative work practices within teams, often emphasising the importance of a common syntax and shared ontology. Approach #17, for instance, aims to provide holistic and comprehensive digital health behaviour change intervention guidance to designers and developers by integrating models from health psychology, persuasive systems design and mHealth app design, into one "unified" digital health intervention taxonomy (Wang, 2019, p.37; Wang, et al., 2019, p.4). Approaches #18 and #19 propose multidisciplinary approaches that aim to integrate gamification, and persuasive technology and situated cognitive engineering, respectively. Approach #20 provides a mHealth app intervention development process that aims to integrate behavioural science theory (stemming from health sciences) and user experience design (stemming from information systems design).

Two of the four integrative approaches (Approaches #17 and #19) aim to guide the development of health promotion behavioural change interventions intended for delivery via digital technologies in general, including various health technologies and mHealth apps specifically. In comparison, the two other approaches (Approaches #18 and #20) aim to provide multidisciplinary guidance for designing and developing mHealth behaviour change intervention apps in particular. Three of the four approaches, namely Approaches #17, #19 and #20, have been used to develop mHealth intervention apps targeting physical activity behaviour change specifically. Approach #20, for example, was used to design, develop and evaluate three different mHealth physical activity apps from three distinguishable perspectives: *Analytic (Cognitive)*; *Social*; and *Affective (Emotional)*. Approach #18, in contrast, has been used to develop a smoking cessation app, *CigBreak*; although, the approach offers insights and lessons learned that are valuable and applicable to the mHealth physical activity behaviour change intervention app context.

With regard to target audience, all four approaches have been used for designing, developing and evaluating digital health interventions intended for the individual and interpersonal socioecological levels of health promotion. Overall, all four approaches emphasise multi- and interdisciplinary collaborative team involvement from the start of a project, and identify methods, artefacts and objects to support collaborative knowledge sharing and work efforts during the design, development and evaluation process. Three of the four approaches (Approaches #17, #18 and #19) review and/or draw from four or more existing approaches, including *Intervention Mapping* (Approach #1), *The CeHRes Roadmap* (Approach #2), *The BIT Model* (Approach #7), *The IDEAS Framework* (Approach #8), *The mHealth App Intervention Development Process* (Approach #9), and *The Person-Based Approach* (Approach #13). However, one approach, Approach #20, does not harness or draw from any existing approaches.

For purposes of length, the Integrative Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.4.2 to 6.4.4.7 are extracted to Appendix I. One summary table and two summary figures for the Integrative Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

## 6.5 An Overall Critical Theoretical Analysis of the Multi- and Interdisciplinary Approaches

The critical thematic and comparative theoretical analysis on the twenty selected multi- and interdisciplinary digital health intervention development approaches yielded a substantial array of comprehensive and in-depth findings across the Health Sciences, Information Systems and Technology, Partnership and Integrative Perspective categories. After writing the finding reports in Sections 6.4.1.1 to 6.4.4.7, a large critical thematic cross-comparative analysis was performed on the findings across the four perspective categories, to consolidate the findings and identify the main overall common themes and subthemes pertinent to the boundary object view and relevant for informing the development of the interdisciplinary framework artefact (Chapter 7).

The overall critical analysis findings are presented and discussed in the same format as Section 6.4, that is in terms of the seven main themes (seven sub-headings, with minor tweaks), based on the template criteria (Table 6.5). The seven main themes cover the: (1) *aims and context*; (2) *actors and communities of practice*; (3) *perspectives, underlying theories, models, tools*

*and existing approaches*; (4) *process nature, steps and activities*; (5) *any design artefacts, boundary objects and supporting methods employed at each process step*; (6) *knowledge boundary contributions*; and (7) *noteworthy limitations and lessons learned*.

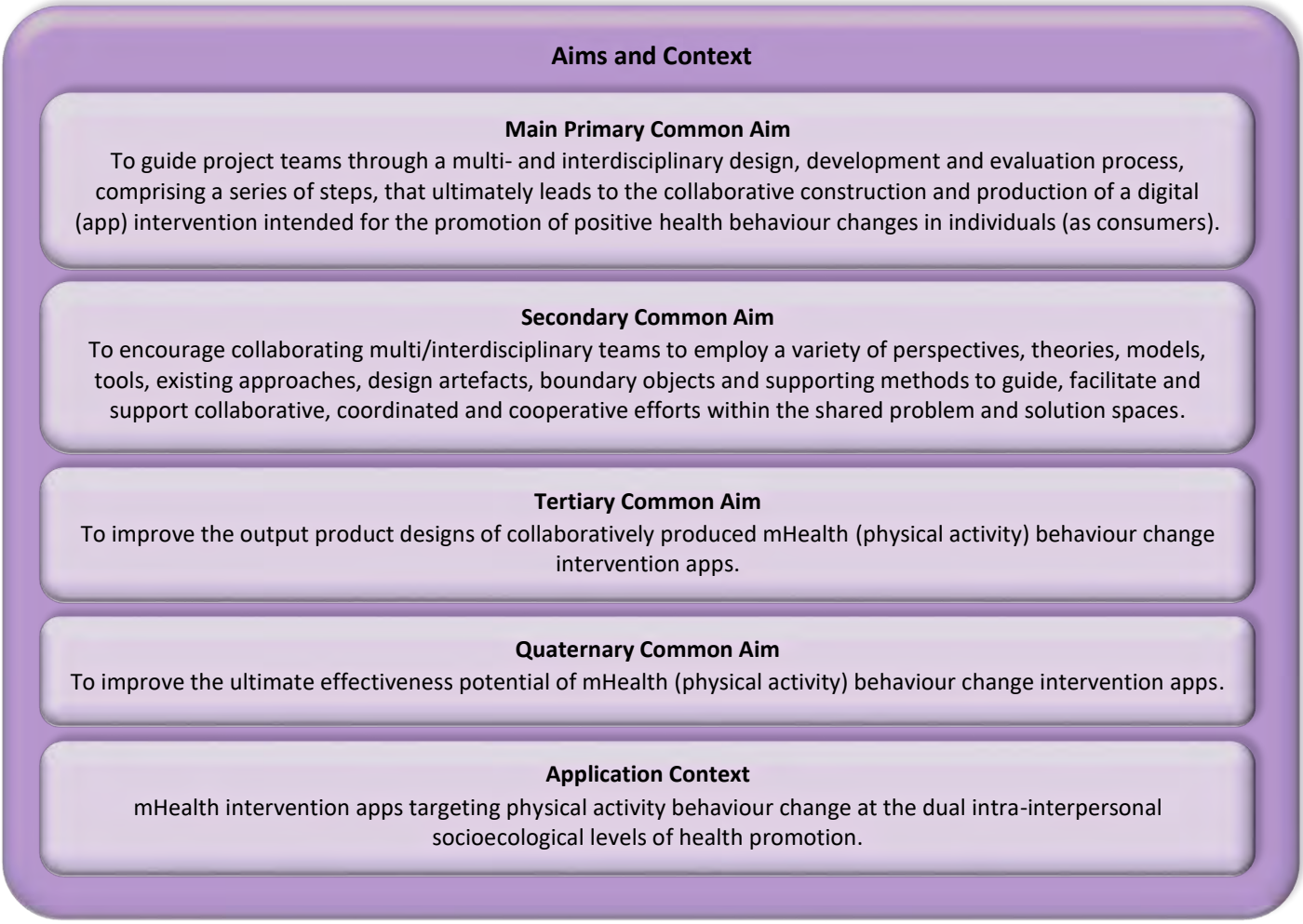
### 6.5.1 Aims and Context

The interdisciplinary mHealth (physical activity) behaviour change intervention app arena operates within a shared design problem and solution boundary space, at the overlapping intersection of several heterogeneous communities of practice. While the philosophical worldviews, theoretical and assumptive frameworks, goals, interests, conceptual models, knowledge, expertise, skills and practices of diverse practice communities often differ, they all share one chief aim. At the crux, they share a *main primary common aim*: *to guide project teams through a multi- and interdisciplinary design, development and evaluation process, comprising a series of steps, that ultimately leads to the collaborative construction and production of a digital (app) intervention intended for the promotion of positive health behaviour changes in individuals (as consumers)*.

Overall, the analysed multi- and interdisciplinary approaches propose collaborative processes that leverage the integration of heterogeneous knowledge, expertise and skills and heteropraxial activities applicable to the design, development and evaluation of digital (app) health behaviour change interventions. As a shared *secondary common aim*, all twenty approaches encourage multi/interdisciplinary collaborating teams to employ a variety of perspectives, theories, models, tools, existing approaches, design artefacts, boundary objects and supporting methods to guide, facilitate and support collaborative, coordinated and cooperative efforts within the shared problem and solution spaces. As an effect of achieving this aim, the twenty approaches share a *tertiary common aim*: to improve the output product designs of collaboratively produced mHealth (physical activity) behaviour change intervention apps. As a result, a *quaternary common aim* seeks: to improve the ultimate effectiveness potential of mHealth (physical activity) behaviour change intervention apps.

In terms of application context, a significant proportion of the selected multi- and interdisciplinary approaches discussed new and existing commercial market and research-based mHealth consumer apps intended for targeting physical activity behaviour change at the dual intra-interpersonal socioecological levels of health promotion. This application context aligns with the contextual landscape Chapters 3 and 4. Some examples of these mHealth

consumer apps include (in no particular order): *MyFitnessPal*; *HelpMeDot!*; *TODAY*; *Puzzle Walk*; *30 Day Fitness Challenge*; *Step Counter*; *Nike+ Running*; *Fitocracy*; *Endomondo*; *OL@-OR@*; *Analytic (Cognitive)*; *Social*; *Affective (Emotional)*; and *Active Coach*; amongst others. Box 6.8 provides a summary overview of the common aims and application context for the twenty multi- and interdisciplinary approaches (across the four perspective categories).




*Box 6. 8: Common Aims and Context of Approaches across the Four Perspective Categories [Source: Researcher's own construction]*

### 6.5.2 Actors and Communities of Practice

Actors and communities of practice participating in the multi/interdisciplinary boundary crossing heteropraxial activities and actively sharing knowledge and contributing to the collaborative design, development and evaluation project process are key to the final mHealth (physical activity) behaviour change intervention app product output. A cross-comparison of the twenty approaches in the four perspective categories reveals several common actor and community of practice themes and subthemes. The identified actors reside in a diversity of

independently established practice communities that hold alternate worldview perspectives, which in turn inform different theoretical frames, perceptions and interpretations of the shared problem and solution space. In addition, given the heteropraxial nature of the mHealth app problem and solution space, these actors are required to traverse their own community's boundaries in order to collaborate in shared boundary spaces with other boundary actors on interdisciplinary mHealth app projects. These boundary spanning manoeuvres essentially has them enter into unfamiliar territories where they lack the necessary all-inclusive and comprehensive set of specialist knowledge, expertise and skills required for efficacious mHealth (physical activity) behaviour change intervention app design, development and evaluation. It is therefore strongly recommended that within the shared boundary space, a collaborating multi/interdisciplinary team first be created and formalised during the initiation stage of the mHealth app project.

Although collaborating together on mHealth app projects, the heterogeneous team members remain rooted and localised within their own respective disciplines and practice communities, yet together in the shared boundary space, engage in perspective-making, perspective-taking and knowledge transfer, translation and transformation processes and practices. The common theme references to the general multi/interdisciplinary team members were "intervention designers", "intervention developers", "designers", "developers", "DHI [digital health intervention] designers" and "DHI developers". Considering these actors stem from a diversity of practice communities, the majority of the twenty approaches explicitly identified and articulated specific knowledge domains, fields of expertise and specialised professions.

The common communities of practice themes include (in no particular order): health promotion; public health; health psychology; health behavioural intervention sciences; health behaviour specialist domains (such as sport science, exercise science, nutrition); information systems; digital information technology; mobile and app design and development; persuasive technology and persuasive systems design; game design and development; human computer interaction; cognitive and usability engineering; systems and software engineering; user-centred and user experience design; computer science; and product development. The common theme specialists and knowledge experts that originate from these fields include: health psychologists; health behavioural intervention programme designers and developers; information systems and digital technology designers, developers and testers; mobile and app designers and developers; game designers and developers; persuasive system designers; human

computer interaction specialists; usability experts; user-centred and user experience design experts; system and software engineers; computer scientists; and product designers and developers. In short, the diverse range of heterogeneous actors are localised within different practice communities, yet together comprise the multi/interdisciplinary collaborating project teams operating within the intersecting shared boundary problem and solution spaces.

Notably, given these actors' localised commitments, some multi- and interdisciplinary approaches discussed the recruitment and selection of team leaders (or project managers) and primary empirical study facilitators. The multi/interdisciplinary team leaders operate as knowledge brokers (boundary brokers) within the shared boundary space where they are able to facilitate and communicate across several intersecting boundaries and are tasked with roles, responsibilities and decision-making powers that allow them to direct, facilitate and support the team throughout the duration of the mHealth intervention app design, development and evaluation process. Importantly though, knowledge brokers are regarded as weakly linked to all of the participating practice communities, yet are full members of none; thus clearly distinguishing their role and positioning from other general (localised) team members. Of the twenty approaches, Approach #16 offers comparably the most valuable contributions concerning this knowledge brokering role and position. Markedly, that these team leaders (knowledge brokers) should be fluent in the languages of all participating communities and that they are responsible for developing, updating and disseminating commonly understandable reports and documents at every step of the mHealth app development process.

In addition to the multi/interdisciplinary team, a common theme identified across all four categories was a recognition of third-party stakeholders, with which the team collaborates, consults or partners. Within this third-party stakeholder theme, common subthemes include (in no particular order): project funders and investors; exercise and weight management consultants; mobile and wireless companies; software app companies and industry consultants; healthcare organisations and providers; legislative and regulatory officials; and policy makers. Another common third-party stakeholder related theme was an emphasis on forming partnerships and collaborations with academic institutions, research groups, firms in industry (for example, the commercial app industry), and open-source software providers (such as LifeGuide). Alongside third-party stakeholders and partnerships, an important common theme identified across all four categories is the indirect and direct involvement of participants as representatives (end users) of the targeted population group. Indirect participation can be

described as a reference to end users' involvement and feedback during mHealth app prototyping and pilot testing studies. Direct participation, in comparison, refers to active engagements and contributions from participants, who themselves, would be involved in the redesigning and refining of a specific mHealth intervention app prototype. All twenty of the multi- and interdisciplinary approaches incorporated indirect target population group representative participation, whereas only the partnership approaches were likely to integrate direct co-design, co-development and participatory design methods.

Table 6.7 provides a summary overview of the nine main actor and community of practice themes, along with their associated theme descriptions, constituting subthemes, and a few (inexhaustive) examples of actors for each theme. Based on these thematic findings and inspired by community of practice theory and Figures 5.2, 5.3 and 5.6 presented in Chapter 5 (Section 5.3.1 and Subsection 5.3.2.2), Figure 6.7 provides a diagrammatic illustration of the common actor, community of practice and multi/interdisciplinary team themes and subthemes.

*Table 6. 7: Key Common Actor and Communities of Practice Themes and Subthemes [Source: Researcher's own construction]*

| Community of Practice Theme | Community of Practice Theme Description | Community of Practice Subthemes | Examples of Actors |
|---|---|---|---|
| **Multi/ Interdisciplinary Team** | The multi/interdisciplinary team of heterogeneous actors are localised in a diversity of practice communities that hold alternate worldview perspectives, yet engage in boundary spanning and knowledge sharing activities within a shared problem and solution space. Multi/interdisciplinary team members can be referred to as digital health intervention designers and developers. | • Team Lead and Project Management and Facilitation<br>• Health Behavioural Intervention Community<br>• Information Systems Community<br>• Health Behavioural Intervention Community<br>• Business and Product Development Community<br>• Computer Science Community<br>• Persuasive Technology and Game Development Community | • Digital Health Intervention Team Designer<br>• Digital Health Intervention Team Developer |
| **Team Lead and Project Management and Facilitation** | Given that heterogeneous team members are localised in different practice communities, team leaders, project managers and primary empirical study facilitators are elected to operate as knowledge boundary brokers within the shared boundary space. Knowledge boundary brokers are weakly linked to all participating practice communities, yet are full members of none, and are tasked with leading, supporting and coordinating the team throughout the project. | • Team Lead (Knowledge Boundary Brokering Practices)<br>• Project Management (Knowledge Boundary Brokering Practices)<br>• Primary Empirical Study Facilitation | • Team Leader (Knowledge Broker)<br>• Project Manager (Knowledge Broker)<br>• Empirical Study Project Facilitator |

| | | | |
|---|---|---|---|
| **Health Behavioural Intervention Community** | Team members localised within the broader health behavioural intervention community primarily adopt a health and intervention design, development and evaluation perspective of the shared problem and solution boundary space. | • Health Promotion Community<br>• Health Psychology Community<br>• Health Behavioural Change Intervention Sciences Community<br>• Health Behaviour Specialist Domain Practice Community (e.g. Sport Sciences, Exercise Sciences) | • Health Psychologist<br>• Health Behaviour Change Intervention Designer<br>• Physical Activity Expert<br>• Exercise Scientist<br>• Personal Trainer |
| **Information Systems Community** | Team members localised within the broader information systems community primarily adopt a digital technology (mobile app) and software design, development and evaluation perspective of the shared problem and solution boundary space. | • Information Systems Community<br>• Mobile and App Design and Development Community<br>• Human Computer Interaction Community<br>• User-Centred and User Experience Design Community(ies)<br>• Systems and Software Engineering Community<br>• Cognitive and Usability Engineering Community | • Information Systems Analyst<br>• Information Systems Designer<br>• Mobile App Designer<br>• User Experience Design Expert |
| **Business and Product Development Community** | Team members localised within the broader business and product development community primarily adopt a business and commercial perspective of the shared problem and solution boundary space by orientating focus towards consumers and product design and development. | • Business Development Community<br>• Product Design and Development Community<br>• Consumer and Mobile App Marketing | • Consumer Market Analyst<br>• Product Designer |
| **Computer Science Community** | Team members localised within the broader computer science community primarily adopt a technical build and programming perspective of the shared problem and solution boundary space by orientating focus towards data structures and algorithms, databases, infrastructure, architecture, Wi-Fi networks, coding, and privacy and security. | • Computer Sciences Community<br>• Mobile Architecture and Infrastructure Community(ies)<br>• Mobile Software Development and Mobile App Server Community(ies)<br>• Database Design and Development Community | • App Developer<br>• Mobile Software Developer<br>• Privacy Expert<br>• Security Expert |
| **Persuasive Technology and Game Development Community** | Team members localised within the broader persuasive technology and game development community primarily adopt health behavioural change support systems and gamification perspectives of the shared problem and solution boundary space. | • Persuasive Technology and Persuasive Systems Design Community(ies)<br>• Health Behavioural Change Support Systems Community<br>• Game Design and Development Community | • Persuasive Systems Designer<br>• Game Designer<br>• Game Developer |

| | | | |
|---|---|---|---|
| **Third Party Stakeholders** | When necessary and appropriate, the multi/interdisciplinary team may partner and consult with a variety of relevant third-party stakeholders during various stages of the project. | • Project Funders and Investors<br>• Health Behaviour Specialist Consultants<br>• Healthcare Organisations<br>• Mobile, Wireless and Software App Companies<br>• Open-Source Software Providers<br>• Academic Institutions and Research Groups<br>• Policy Makers, Legislative and Regulatory Officials | • Physical Activity Expert Consultant<br>• Health Behaviour Change Intervention App Researcher<br>• Mobile App Consultant |
| **Target Population Group Representatives (End Users)** | Sample representatives of the defined target population group may collaborate and/or engage with the multi/interdisciplinary team at various stages of the project process, and may directly and/or indirectly participate in a variety of design, development and evaluation activities. | • Direct End User Participation Involvement<br>• Indirect End User Participation Involvement | • End User Participants |

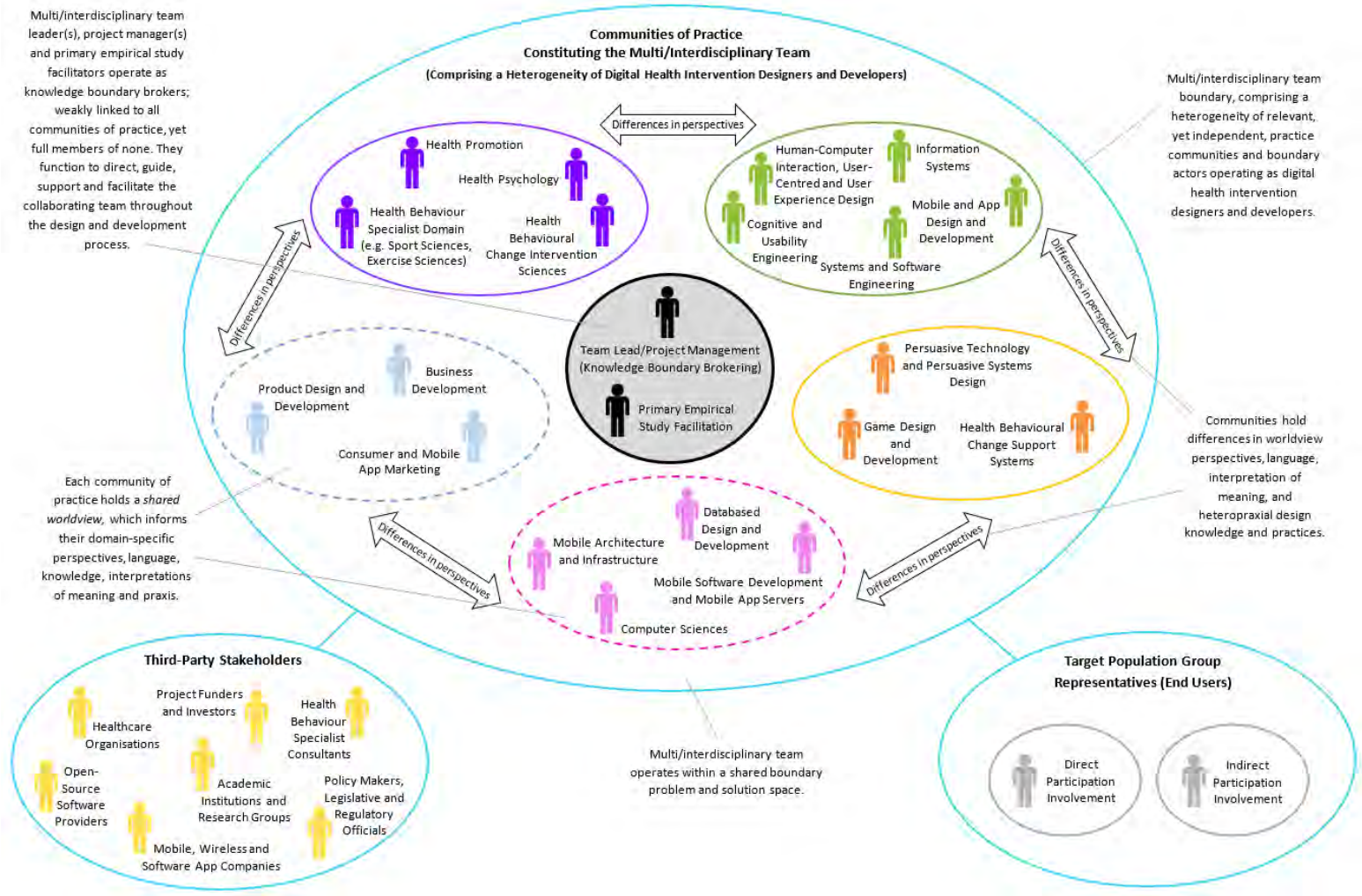



*Figure 6. 7: Key Common Actor, Community of Practice and Multi/Interdisciplinary Team Themes and Subthemes across the Four Perspective Categories [Source: Researcher's own construction]*

### 6.5.3 Perspectives, Underlying Theories, Models, Tools and Existing Approaches

A cross-comparison of the four perspective categories reveals a number of common *perspectives* adopted towards the multi/interdisciplinary mHealth behaviour change intervention app design, development and evaluation project process. Noteworthy common subtheme umbrella perspectives include, namely: (1) *health promotion and health behavioural change intervention sciences*; (2) *information systems*; (3) *persuasive systems and gamification*; and (4) *business, commercial/consumer app market and product development*.

Under the (1) *health promotion and health behavioural change intervention sciences perspective umbrella*, common sub-subthemes include (in no particular order): health promotion; health psychology; health behavioural intervention sciences; the socioecological approach; healthy lifestyle (behaviour) modification and wellbeing (self-)management; and physical activity promotion. Under the (2) *information systems perspective umbrella*, common sub-subthemes include (in no particular order): systems thinking; systems and software engineering; human factors and cognitive engineering; human/user-centred design; human computer interaction; user interface and user experience design; the agile software development lifecycle approach; design thinking; innovative thinking; computer supported cooperative work; and the participatory design approach. Associated with the information systems perspective subtheme are two related perspective subthemes, namely the (3) *persuasive technology/systems and gamification perspective umbrella*; both of which offer valuable knowledge, expertise and skill contributions to mHealth (physical activity) behaviour change intervention app design, development and evaluation. Another two perspective subthemes related to the information systems perspective are the mHealth intervention and digital technology intervention perspectives, and the consumer health informatics perspective (introduced in Chapter 4). These subthemes further relate to the (4) *business, commercial/consumer app market and product development perspective umbrella*, particularly in terms of the consumer app market stores (such as Google Play), the commercial app industry, business management, and product development sub-subthemes.

A common theme identifiable across the four perspective categories is an emphasis on creating a solid *underlying theoretical foundation* to underpin both the multi/interdisciplinary approach as well as the digital mHealth behaviour change intervention app product. In other words, validated theoretical frameworks, models and constructs should underlie both the design,

development and evaluation process (the approach) and the design product (the mHealth physical activity behaviour change intervention app). Underpinning evidence-based theoretical frameworks and methods enhance the credibility, reliability and validity of a proposed design, development and evaluation process (approach). In the first Health Sciences Perspective category, for example, Approach #2 is based on and informed by a critical analysis of sixteen existing theoretical frameworks. In the second Information Systems and Technology Perspective category, for instance, Approach #6 specifies a "theoretical basis" as a crosscutting theme underpinning its proposed mHealth intervention development process. In the third Partnership Perspective category, Approach #14 reviews several theory-informed participating design methods and behaviour change frameworks to inform the development of the proposed process, and Approach #15 fuses what the authors describe as "validated theoretical frameworks" with culturally tailored theoretical models. Lastly, in the fourth Integrative Perspective category, an example of theoretical underpinning is apparent in Approach #17, where the authors expressly articulate that "due to their interdisciplinary nature, DHIs [digital health interventions] are guided and influenced by theories… from different research communities", to which they propose a "holistic framework [TUDER] that embeds [various] theories". Another Integrative Perspective example was identified in Approach #19, where the authors describe their approach as "generat[ing] building blocks from theory originating from different relevant disciplines" that "is expected to contribute to a sound [theory-based] design rationale".

*Evidence-based theoretical underpinnings* also strengthen the reliability and validity of a collaboratively produced design product (a mHealth physical activity behaviour change intervention app). When designing and developing the theoretical foundation that will be used to underpin the mHealth behaviour change intervention app, a common pool of individual and interpersonal theories, models and constructs originating from health, behavioural, cognitive and social psychology were identifiable across all twenty of the multi- and interdisciplinary approaches. Common theory and theoretical construct subthemes include: social cognitive theory (SCT); self-determination theory (SDT); self-regulation theory; self-efficacy theory; self-identity theory; social learning theory (SLT); theory of reasoned action (TRA); theory of planned behaviour (TPB); goal setting theory (GST); protection motivation theory (PMT); and theories of social support. All of these common theory and theoretical construct subthemes were introduced and described as key health behaviour change theories for physical activity behaviour change at the dual intra-interpersonal socioecological levels in Chapter 3, Subsection

3.5.1. The findings of this critical thematic and comparative analysis therefore confirm these theories and theoretical constructs detailed in the contextual landscape literature (Chapter 3). In addition, common theoretical framework and model subthemes include the: transtheoretical model (TTM); health belief model (HBM); elaboration likelihood model (ELM); integrated behaviour change model (IBCM); integrated behaviour model (IBM); and the precaution adoption process model (PAPM). The HBM was described in Chapter 3, Section 3.5.1.

Further critical comparative analysis across the four perspective categories reveals common *model and tool* subthemes: (1) *coding and development health behaviour change taxonomies*; (2) *health behaviour change intervention frameworks and models*; (3) *information systems and mobile app models*; (4) *persuasive technology/systems design models*; (5) *gamification taxonomies and models*; and (6) *evidence-based standards, codes of practice, recommendation guidelines and checklists*.

Under the (1) *coding and development taxonomies* subtheme, sub-subthemes include the CALO-RE Taxonomy for physical activity and healthy eating and the BCT Taxonomy v1 (as two coding taxonomies), and the Taxonomy of Behaviour Change Methods (TBCM) (as one development taxonomy). Under the (2) *frameworks and models* subtheme, sub-subthemes include the Theoretical Domains Framework (TDF), the Behaviour Change Wheel (BCW), the Capability-Opportunity-Motivation Behaviour Model (COM-B), and the PRECEED-PROCEED Model. Under the (3) *information systems model* subtheme, sub-subthemes include the Health-ITUEM, just-in-time adaptive intervention (JITAI) models, and Unified Modelling Language (UML) tools and software; computer assisted design software; and 3D modelling and (Android OS and Apple iOS) app design and development software. Under the (4) *persuasive models* subtheme, sub-subthemes include the Functional Triad, the Fogg Behavioural Model (FBM) and the Persuasive Systems Design Model (PSDM). Under the (5) *gamification* subtheme, sub-subthemes include gamification taxonomies and gamification models. Under the (6) *standards, codes of practice, guidelines and checklist* subtheme, sub-subthemes include: the British Standards Institution Code of Practice for Health and Wellbeing Apps; the WHO's Global Recommendations for Physical Activity; accessibility standards (such as WCAG 2.0, W3C/WAI); quality, privacy and security standards; the CONSORT-EHEALTH statement and checklist; and the mHealth Evidence Reporting and Assessment (mERA) checklist. Many of these model and tool subthemes and sub-subthemes were identified and discussed in Chapters 3 and 4 and included in Appendices D, E and F.

Lastly, in terms of the *existing approaches* theme, many of the twenty approaches are informed by, draw from and/or integrate aspects of existing multi- and interdisciplinary approaches to enrich the credibility, reliability and validity of their proposed approaches. Approach #8, for instance, reviews and incorporates several existing theories and approaches in its theoretical foundation, to inform the development of *The IDEAS Framework*, which the authors describe as "the best combination of approaches available". Two other approaches identified as frequently integrated into the analysed multi- and interdisciplinary approaches were Approach #1 *(Intervention Mapping)* and Approach #7 *(The BIT Model and The BIT-Tech Framework)*.

Overall, in reference to Weick (1989), a richer heterogeneity of thought trials can be generated and cultivated within the mind of the researcher by integrating and employing a multi/interdisciplinary diversity of perspectives, underlying theories, models, tools and existing approaches. This heterogeneity in thought trials ultimately leads to the development of better (design) theory, in comparison to homogeneous thought trials that draw from a singular perspective, theory, model, tool and/or existing approach (Weick, 1989). Table 6.8 provides a summary overview of the common themes and subthemes pertaining to perspectives, underlying theories, models, tools and existing approaches identified across the four perspective categories.

*Table 6. 8: Common Perspective, Underlying Theory, Models, Tools and Existing Approach Themes and Subthemes [Source: Researcher's own construction]*

| Perspective Theme | Underlying Theory Theme |
|---|---|
| • Health promotion and health behavioural change intervention sciences perspective, including socioecological, wellbeing and lifestyle (self-) management, and physical activity perspectives<br>• Information systems perspective<br>• Persuasive systems and gamification perspective<br>• Business, commercial/consumer app market and product development perspective | • Evidence-based theory, frameworks, models, theoretical constructs and methods underlying both:<br>o the design, development and evaluation process (approach)<br>o the design product (mHealth intervention app)<br>• Theories, models and constructs: SCT; SDT; SLT; TRA; TPB; GST; PMT; TTM; HBM; ELM; IBCM; IBM; PAPM; self-regulation; self-efficacy; social support theory. |
| **Model and Tool Theme** | **Existing Approach Theme** |
| • Coding and development health behaviour change taxonomies<br>• Health behaviour change intervention frameworks and models<br>• Information systems and mobile app models<br>• Persuasive technology/systems design models<br>• Gamification taxonomies and models<br>• Evidence-based standards, codes of practice, recommendation guidelines and checklists | • Most frequently referenced existing multi- and interdisciplinary approaches:<br>o Intervention Mapping (Approach #1)<br>o The BIT Model and BIT-Tech Framework (Approach #7)<br>o The IDEAS Framework (Approach #8) |

### 6.5.4 Process Nature, Steps and Activities

***The Nature of Multi- and Interdisciplinary Approaches***

The essential nature and characteristics of multi- and interdisciplinary approaches influences the way project team members communicate and share heterogeneous knowledge, expertise and skills, and coordinate and collaborate heteropraxial activities during the mHealth behaviour change intervention app design, development and evaluation process. An overview of the findings across the four perspective categories reveals common process nature themes as pertaining to the process (1) *structure*, (2) *quality*, and (3) *agility*.

In terms of (1) *structure*, some of the multi- and interdisciplinary approaches were described as *systematic*, referring to a more or less methodical, organised and logical nature. Some approaches were described as *cumulative*, meaning the outputs of prior steps in a process are generally used as inputs to inform successive process steps, and that the work performed and artefacts created continue to gradually develop and improve over the duration of the enacted process. Several approaches were described as *non-linear*. Linearity suggests that team members are required to follow the steps within an approach or process in an expected order or sequence, whereas non-linearity indicates that team members need not necessarily follow the prescribed steps in an orderly or sequential manner.

With regard to (2) *quality*, most of the twenty approaches were described as *theory-based* and *evidence-based*. Theory-based essentially indicates that the steps within a process, or the process as a whole, are built on and/or informed by verified theories and theoretical frameworks and models. Evidence-based conveys that the steps within a process, or the process as a whole, has been applied in empirical practice and demonstrates scientific proof (hence the word 'evidence') for validity, objectivity, credibility and reliability. These process nature subthemes pertaining to theory-based and evidence-based qualities links to the underlying theory, model and tool and existing approach themes discussed in Section 6.5.3 above (Table 6.8). Moreover, a small handful of approaches referred to their processes as *pragmatic* (practical) in nature. Pragmatic essentially denotes an approach and process that is concerned with practical, realistic, sensible and real-world application considerations, rather than theoretical considerations. Important to note is that a pragmatic approach can still be theory-based or theory-informed, but quintessentially aims to conduct a process in a practical and sensible way.

In terms of (3) *agility*, some approaches were described as *flexible* and *adaptable*, which is well suited to the continuously evolving mHealth behaviour change intervention app context. While some approaches were described as prescribing a somewhat systematic sequence, it is imperative to consider that depending on the strengths, knowledge, expertise, skills and experience of a given multi/interdisciplinary team, the process steps and activities can often be applied in a flexible and adaptive manner. For Approach #8, for example, Mummah, et al. (2016, p.5) explain that "the multidisciplinary teams… that stand to benefit the most from applying the IDEAS framework are those who will apply the stages flexibly, pursuing multiple stages in parallel, in combination, more than once, and/or iteratively, as new directions are explored and refined". Mummah, et al. (2016, p.5) also describe the ten IDEAS approach phases as "more like a system of overlapping spaces, rather than a sequence of orderly steps", and highlight that "some high-performing [multidisciplinary collaborating] teams have been shown to combine, in particular, the ideate, prototype, and gather phases, rapidly shifting between them as needed". On a similar note, many of the multi/interdisciplinary approaches, specifically those particularised to the mobile app and physical activity behaviour change intervention contexts, share agility related subthemes pertaining to an *iterative* (or rapid iterative), *cyclical* (or *feedback looping*), *dynamic*, *reflective*, *reflexive* and *continuous* nature.

Table 6.9 provides a summary overview of the common themes and subthemes used to describe the general process nature of multi- and interdisciplinary approaches for guiding the design, development and evaluation of mHealth physical activity behaviour change intervention apps.

*Table 6. 9: Common Process Nature Themes and Subthemes*
*[Source: Researcher's own construction]*

| **Nature of Process Themes** | **Nature of Subthemes** | | | |
|---|---|---|---|---|
| • Structure | • Systematic | | • Non-linear | |
| • Quality | • Theory-based | • Evidence-based | • Pragmatic | |
| • Agile | • Iterative<br>• Continuous<br>• Cumulative | • Adaptive<br>• Flexible<br>• Dynamic | • Cyclical and feedback loops | • Reflective<br>• Reflexive |

***The Process Steps and Activities of Multi- and Interdisciplinary Approaches***

The nature of the multi/interdisciplinary approach drives and underlies the steps and activities of the mHealth physical activity behaviour change intervention app intervention design, development and evaluation process. The process steps and comprising activities constitute the essential elements of the multi/interdisciplinary approach. A critical cross-comparative overview of the thematic findings across the four perspective categories (discussed specifically in Subsections 6.4.1.4, 6.4.2.4, 6.4.3.4 and 6.4.4.4 in Appendix I) revealed nine overarching themes pertaining to the multi/interdisciplinary process steps. A cross-comparative analysis drawing from Table Appendix I.1 and Figure Appendix I.1 (Subsection 6.4.1.4), Table Appendix I.2 and Figure Appendix I.3 (Subsection 6.4.2.4), Table Appendix I.3 and Figure Appendix I.5 (Subsection 6.4.3.4), and Table Appendix I.4 and Figure Appendix I.7 (Subsection 6.4.4.4) informed a consolidated cross-comparative thematic overview diagram of the common process steps and activities across the four perspective categories, presented in Figure 6.8.

As outlined in the thematic map (Figure 6.8), the multi- and interdisciplinary process includes nine common main theme steps, with three of the steps referencing two distinct parts, and all nine steps include several activities. As presented in Figure 6.8, the process step themes are: (1) *team, business and project formalisation*; (2) *problem understanding*; (3) *theoretical and conceptual solution development* (including theoretical level part 1 for the theoretical base, and theoretical level part 2 for the conceptual base); (4) *instantiated conceptual and technological solution design* (including instantiation level part 1); (5) *instantiated concrete and material solution design* (including instantiation level part 2); (6) *formative evaluation* (including part 1 for pilot testing, and part 2 for beta testing); (7) *implementation*; (8) *summative evaluation*; and (9) *post-market release surveillance*. Corresponding to Figure 6.8, Table 6.10 details the aims and descriptions for each of the nine multi/interdisciplinary process steps.

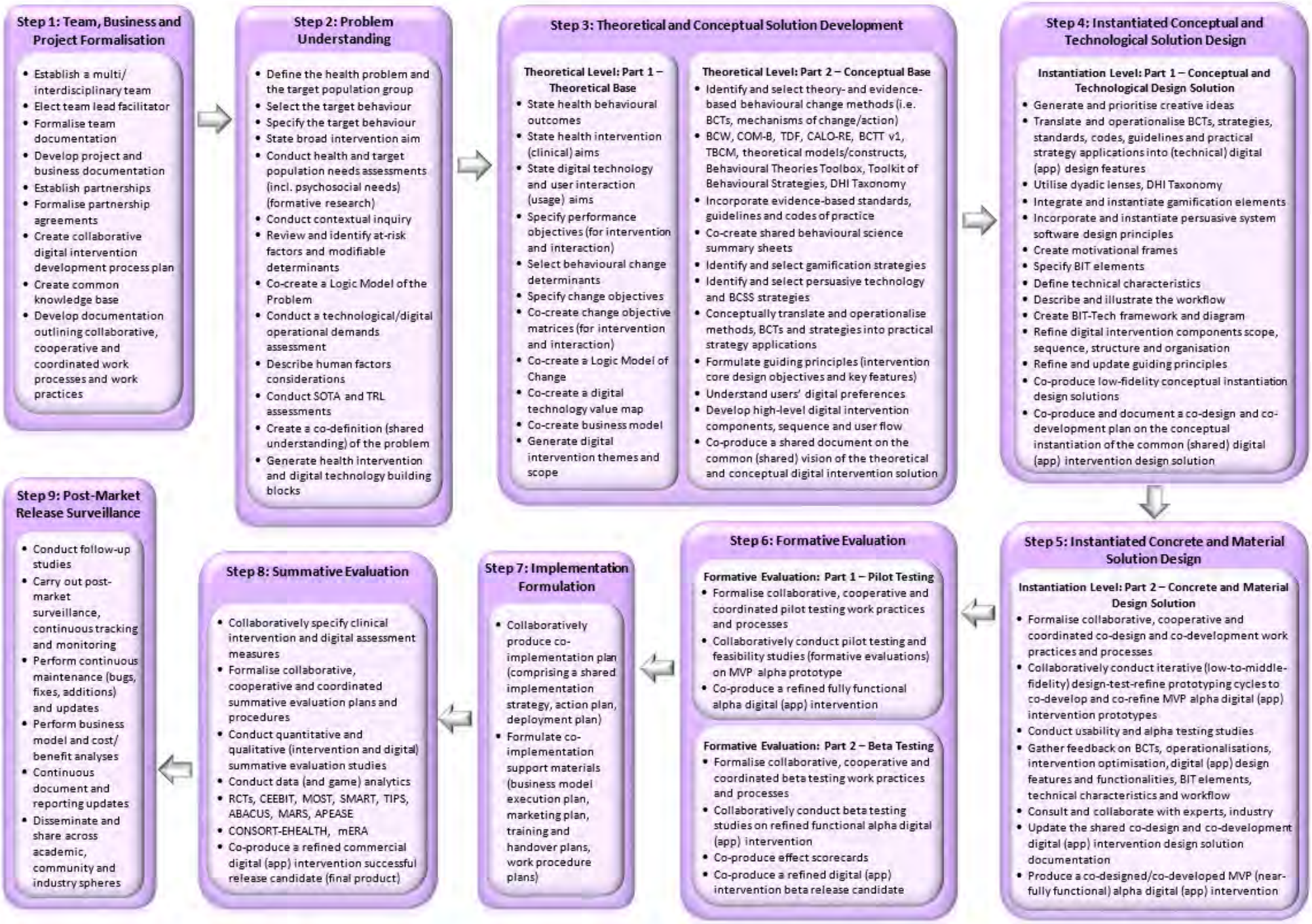



*Figure 6. 8: Common Process Step and Activity Themes and Subthemes across the Four Perspective Categories [Source: Researcher's own construction]*

*Table 6. 10: Aims and Descriptions of Common Process Step and Activity Themes and Subthemes across the Four Perspective Categories [Source: Researcher's own construction]*

| Process Step | Aim and Description |
|---|---|
| **Step 1:** ***Team, Business and Project Formalisation*** | ***Step 1 Aim:*** Establish the multi/interdisciplinary project team, elect a team lead and establish project partnerships. ***Description****:* Co-develop team, business model and project documentation, and formalise partnership agreements. Co-create the team's collaborative design, development and evaluation process plan, common knowledge base and shared work practice documentation. |
| **Step 2:** ***Problem Understanding*** | ***Step 2 Aim****:* Gain an in-depth understanding of the health problem, the target health behaviour and the target population group. ***Description****:* Conduct health behavioural, target group and technological/digital needs and demands assessments. Explication activities informs the team's formation of a co-definition for the shared problem space, thereby generating the initial building blocks from both the health behavioural intervention and digital technology perspectives. |
| **Step 3:** ***Theoretical and Conceptual Solution Development*** | ***Step 3 Aim****:* Design and develop the theoretical and conceptual foundation of the mHealth behaviour change intervention app. ***Aim and Description of Theoretical Level Part 1 (The Theoretical Base)****:* Specify the health intervention (clinical) and digital technology and user interaction (usage) aims, and the associated performance and change objectives. Collaboratively outline the digital health behaviour change intervention app's themes and scope. Co-create the shared health intervention, digital and business objectives. ***Aim and Description of Theoretical Level Part 2 (The Conceptual Base)****:* Identify and select conceptual elements: appropriate theory and evidence-based behaviour change methods, BCTs, standards, guidelines, and persuasive and gamification strategies. With an understanding of the target group's digital user preferences, translate the conceptual elements into practical strategy applications at the theoretical level. Co-develop high-level flow intervention and user maps, and co-produce a shared vision for the mHealth app's theoretical and conceptual base. |
| **Step 4:** ***Instantiated Conceptual and Technological Solution Design*** | ***Step 4, Instantiation Level Part 1 Aim****:* Detail the translation and operationalisation of the theoretical and conceptual solution (at a theoretical level) into a conceptual and technological design solution (at an instantiation level). ***Description****:* Design activities aim to instantiate practical strategy applications into conceptual interactive digital software mobile app design features by employing and applying principles of gamification, persuasive systems design and motivational framing. Specify the BIT elements, technical characteristics, workflow and BIT-Tech framework. Co-create the low-fidelity conceptual design solution. Co-produce a shared co-design and co-development plan documenting the digital health behaviour change intervention app's conceptual and technological design solution. |
| **Step 5:** ***Instantiated Concrete and Material Solution Design*** | ***Step 4, Instantiation Level Part 2 Aim****:* Produce co-designed/co-developed concrete and material design instantiations of the mHealth app (in various low-, middle- and high-fidelity forms). ***Description:*** Conduct a series of iterative design-test-refine prototyping cycles. Conduct usability and alpha testing studies to gather feedback on the mHealth app's design. Produce a co-designed/ co-developed MVP (near fully functional) alpha mHealth app prototype. |
| **Step 6:** ***Formative Evaluation*** | ***Step 6 Aim:*** Conduct formative evaluation testing on the MVP alpha app prototype to gather further feedback from participant users (representatives of the target population group). ***Aim and Description of Part 1 (Pilot Testing)****:* Conduct pilot and feasibility testing studies to gather feedback and co-produce a refined fully functional alpha app. ***Aim and Description of Part 2 (Beta Testing)****:* Conduct beta testing studies on the alpha app version to further improve its design, resulting a co-produced, refined mHealth app as a beta release candidate. |
| **Step 7:** ***Implementation Formulation*** | ***Step 7 Aim and Description:*** Detail and document the co-implementation strategy, action plan and deployment plan, along with relevant co-implementation support materials, such as the recruitment plan, business model execution plan, work procedure plans, and training and handover plans. |
| **Step 8:** ***Summative Evaluation*** | ***Step 8 Aim***: Specify, formalise and conduct quantitative and qualitative (intervention and digital) summative evaluation studies on the beta release candidate to assess and measure its efficacy, effectiveness, quality and usability over time. ***Description****:* Findings from summative evaluation studies to inform a further refined, co-produced commercial mHealth consumer app as a successful release candidate (final product). |
| **Step 9:** ***Post-Market Release Surveillance*** | ***Step 9 Aim***: Conduct post-market surveillance on the successful app candidate (final product) after it has been publically released to consumers on the commercial app market (e.g. Google Play Store and Apple App Store). ***Description****:* Conduct follow-up studies (with real-world users). Perform continuous tracking and monitoring, ongoing maintenance and updates on the app. Perform frequent business model and cost/benefit analyses. Track, document, report and disseminate project updates across academic, community and industry spheres. |

### 6.5.5 Design Artefacts, Boundary Objects and Supporting Methods

When carrying out the multi/interdisciplinary collaborative process steps and activities, project teams refer to, employ and utilise a broad range and diversity of design artefacts, boundary objects and supporting methods. These artefacts and objects essentially enable, facilitate and mediate cross-community team communication, coordination, cooperation and collaboration, and support team members in performing heteropraxial design, development and evaluation activities within the shared problem and solution boundary space.

A critical cross-comparative overview of the thematic and comparative findings across the four perspective categories (discussed specifically in Subsections 6.4.1.5, 6.4.2.5, 6.4.3.5 and 6.4.4.5 in Appendix I) revealed a diversity of design artefacts, boundary objects and supporting methods functioning as inputs and outputs in the nine multi/interdisciplinary process steps (and activities). A cross-comparative analysis drawing from Figure Appendix I.2 (Subsection 6.4.1.5), Figure Appendix I.4 (Subsection 6.4.2.5), Figure Appendix I.6 (Subsection 6.4.3.5), and Figure Appendix I.8 (Subsection 6.4.4.5) informed a consolidated cross-comparative thematic overview diagram of the common input and output design artefacts, boundary objects and supporting methods, presented in Figure 6.9. Corresponding to Figure 6.9, Table 6.11 describes the nature of the inputs into and outputs produced from each of the nine multi/interdisciplinary process steps.


Step 1: Team, Business and Project Formalisation
Inputs
• Team member and leader selection and recruitment questions and guidelines
• Team documentation guidelines, templates
• Project and business documentation guidelines
• Stakeholder analysis
• Partnership agreement procedures and guidelines
• Shared syntactic and semantic (common knowledge base) creation guidelines
• Collaborative digital intervention development process plan guidelines
• Multi-disciplinary team work process and practice guidelines
• Gating questions
Outputs
• Team member list with CoPs
• Team contract and culture canvas
• Team leader description
• Team management and process facilitation documentation
• Team communication, decision-making and negotiation processes
• Teamwork practice and process guidelines
• Project documentation (vision statement, requirement specifications, funding, resources)
• Business model canvas
• Market analysis report findings
• Stakeholder analysis report
• Partnership agreements
• Gating answers report
• Shared syntactic and semantic common knowledge base
• Collaborative digital intervention development process plan
• Multi-disciplinary team documentation outlining collaborative, cooperative and coordinated work processes and practices
Step 2: Problem Understanding
Inputs
• Health problem and target population group needs assessment guidelines
• Contextual inquiry
• Guiding principles (#8)
• Literature, meta-analyses, findings from experts, empirical and epidemiological studies
• WHO Recommendations for Physical Activity
• Existing commercial apps
• PROCEED Model
• Technological/digital operational demands assessment guidelines
• Human factors principles
• SOTA and TRL assessments
• Primary (HS, PD, IS) qualitative & quantitative research methods
• MdTS workshop guidelines
• Ethical considerations, protocols and procedures
• Co-definition and shared understanding guidelines
Outputs
• Health problem statement
• Target population group spec
• Target behaviour specification
• Broad intervention aim statement
• Health and target population needs assessment report
• Contextual inquiry report
• SEM Model
• Literature, meta-analysis, expert and empirical reports
• Determinants review findings
• Logic Model of the Problem
• Technological/digital operational demands assessment
• Human factors considerations
• SOTA and TRL assessments
• Primary study report findings
• Ethical approval documents
• Co-definition (shared understanding) of the problem
• Health intervention and digital technology building blocks
• IDEAS checklist (1-5)
• TUDER checklist (1-3)
Step 3: Theoretical and Conceptual Solution Development
Inputs: Theoretical Level: Part 1 – Theoretical Base
• Outputs from Step 2
• Health intervention (clinical) aims template
• Digital technology and user interaction (usage) aims template
• Guidelines for specifying performance objectives (intervention and interaction)
• Change objective matrices guidelines
• Literature, meta-analyses, expert findings and empirical studies
• WHO Recommendations for Physical Activity
• Existing commercial apps
• Digital technology value map guidelines
• Business model and value spec guidelines
• Digital intervention theme and scope guidelines
Outputs: Theoretical Level: Part 1 – Theoretical Base
• Health behavioural outcomes statement
• Health intervention (clinical) aims statement and specifications
• Digital technology and user interaction (usage) aims statement and specifications
• Selected determinants list
• Performance objective specifications (intervention and interaction)
• Change objectives list
• Intervention change matrix
• Interaction change matrix
• Logic Model of Change
• Existing apps report
• Digital technology specs list and value map
• Business model
• Cost-benefit analysis
• Value specification
• Digital intervention themes, subthemes and scope
Inputs: Theoretical Level: Part 2 – Conceptual Base
• Outputs from Step 3 – Part 1
• Theoretical and conceptual base development guidelines
• BCW, COM-B, TDF, CALO-RE, BCTT v1, TBCM, theoretical models/constructs, Behavioural Theories Toolbox, Toolkit of Behavioural Strategies, DHI Taxonomy
• Evidence-based standards, guidelines and codes of practice
• Gamification models and strategies
• Persuasive technology and BCSS models
• Shared behavioural science summary sheets
• Logic modelling techniques
• Conceptual translation and operationalisation guidelines
• Guidelines for creating guiding principles
• Literature, expert findings, empirical studies
• Existing commercial apps
• Primary (HS, PD, IS) qualitative and quantitative research methods
• Ethical considerations, protocols, procedures
• Users' digital preference guidelines
• Guidelines for high-level digital intervention components, sequence and user flow
• Co-creation and common (shared) vision development guidelines
Outputs: Theoretical Level: Part 2 – Conceptual Base
• Selected theoretical models and theory- and evidence-based methods (BCTs, mechanisms)
• BCTs and strategies list
• Standards, guidelines and codes of practice list
• Gamification strategies list
• Persuasive technology and BCSS strategies list
• Shared behavioural science summary sheets
• Intrinsic process motivators description
• Theory-intervention function table
• Theory-intervention function-BCT table
• Method-BCT-practical strategy application table
• Ranked and prioritised content modules
• Literature, meta-analysis, expert, empirical reports
• Existing commercial apps review, findings report
• Primary (HS, PD, IS) study report findings
• Ethical approval documentation
• Guiding principles (intervention core design objectives and key features)
• Users' digital preferences table
• High-level digital intervention components, sequence and user flow
• Co-produced document on the common (shared) vision of the theoretical and conceptual digital intervention solution
• IDEAS checklist (6-7)
• TUDER checklist (4-6)
Step 4: Instantiated Conceptual and Technological Solution Design
Inputs: Instantiation Level: Part 1 – Conceptual and Technological Design Solution
• Outputs from Step 3 (Parts 1 and 2)
• Creative idea generation and expressive methods
• Creative divergent thinking techniques
• Conceptual instantiation translation and operationalisation guidelines
• Dyadic lenses, DHI Taxonomy
• Gamification elements instantiation guidelines
• PSDM, FBM, Functional Triad
• Motivational frame creation guidelines
• BIT and BIT-Tech Model (instantiation) guidelines
• JITAI methods and techniques
• Interaction (microsuasion) guidelines
• Logic modelling techniques
• User and intervention delivery flow guidelines
• Final intervention mapping table template
• Complex instantiation table guidelines
• Guidelines for co-creating design rationale, design scenarios, requirements and claims specifications
• UML and OOD guidelines and narrative templates
• Literature, meta-analyses, expert findings and empirical studies
• Existing commercial apps
• Primary (HS, PD, IS) qualitative and quantitative research methods
• Ethical considerations, protocols and procedures
• Digital intervention components scope, sequence, structure and organisation guidelines
• Guiding principles
• Guidelines for co-creating low-fidelity conceptual instantiation design solutions
• Guidelines for co-producing the co-design and co-development plan on conceptual instantiation of the shared digital (app) intervention design solution
Outputs: Instantiation Level: Part 1 – Conceptual and Technological Design Solution
• Creative ideas generation and expression findings
• Creative divergent thinking findings
• Dyadic lenses and DHI Taxonomy report findings
• Gamification elements instantiation specifications
• PSD principles list and instantiation specifications
• Motivational frames
• BIT elements specification
• Technical characteristics specification
• Workflow (and JITAI) description and diagram
• BIT-Tech framework and diagram
• Interaction (microsuasion) specification
• Intervention content and message specifications
• Intervention delivery and user journey flow diagrams
• Final intervention logic model and mapping table
• User app design feature (and decision) preference tables
• Complex instantiation tables (methods, BCTs, strategies, standards, codes, guidelines and practical strategy applications into (technical) digital (app) design features)
• Shared design rationale, design scenarios, requirements and claims specifications
• UML and OOD diagrams and narratives
• Communications flow, user workflow, information flow, interaction flow diagrams
• Literature, meta-analysis, expert and empirical reports
• Existing commercial apps review and findings report
• Primary (HS, PD, IS) study report findings
• Ethical approval documentation
• Refined digital intervention components scope, sequence, structure and organisation plan
• Refined and updated guiding principles
• Low-fidelity conceptual instantiation design solutions
• Co-produced co-design and co-development document plan on the conceptual instantiation of the common (shared) digital (app) intervention design solution
• IDEAS checklist (8-11)
• TUDER checklist (7-9)
Step 5: Instantiated Concrete and Material Solution Design
Inputs: Instantiation Level: Part 2 – Concrete and Material Design Solution
• Outputs from Step 3 and Step 4
• Collaborative, cooperative and coordinated co-design and co-development work practice and process document guidelines
• Syntactic and semantic common knowledge base development guidelines
• Common glossary guidelines
• Shared ontology development guidelines
• Shared intervention and interaction concept map creation guidelines
• MdTS (Tech, HCI) and co-design/co-development workshops
• Prototyping (low-to-high-fidelity) methods, techniques, materials
• Alpha, usability/UX testing methods, techniques, materials
• Prototype, alpha, usability, UX testing scenario guidelines
• Literature, meta-analyses, expert findings and empirical studies
• Primary (HS, PD, IS) qualitative and quantitative research methods
• Ethical considerations, protocols and procedures
• User feedback findings from iteration cycles
• Expert and industry consultations and workshops
• Existing commercial apps
• Health-ITUEM, CAD, 3D modelling and app simulation software
• Quality, privacy and security standards
• Accessibility standards (WCAG 2.0, W3C/WAI)
• Gating questions
Outputs: Instantiation Level: Part 2 – Concrete and Material Design Solution
• Collaborative, cooperative and coordinated co-design and co-development work practice and process documentation
• Syntactic and semantic common design and development knowledge base
• Common consensus glossary
• Shared ontology
• Shared intervention and interaction concept map
• MdTS (Tech, HCI) and co-design/co-development workshops report
• Documentation on iterative prototype and alpha study findings
• Detailed prototype, alpha, usability, UX testing scenarios
• Co-produced documentation report on user feedback findings
• Low-to-middle-fidelity DBOs (storyboards, mock-ups)
• High-fidelity DBOs (simulations, MVP-alpha prototypes)
• Literature, meta-analysis, expert, empirical reports
• Existing commercial apps review, findings report
• Primary (HS, PD, IS) study report findings
• Ethical approval documentation
• Expert and industry consultations and workshops report
• Updated shared co-design and co-development digital (app) intervention design and development solution documentation
• Co-designed/co-developed MVP (near-fully functional) alpha digital (app) intervention
• Gating answers report
• IDEAS checklist (8-20)
• Updated TUDER checklist (7-9)

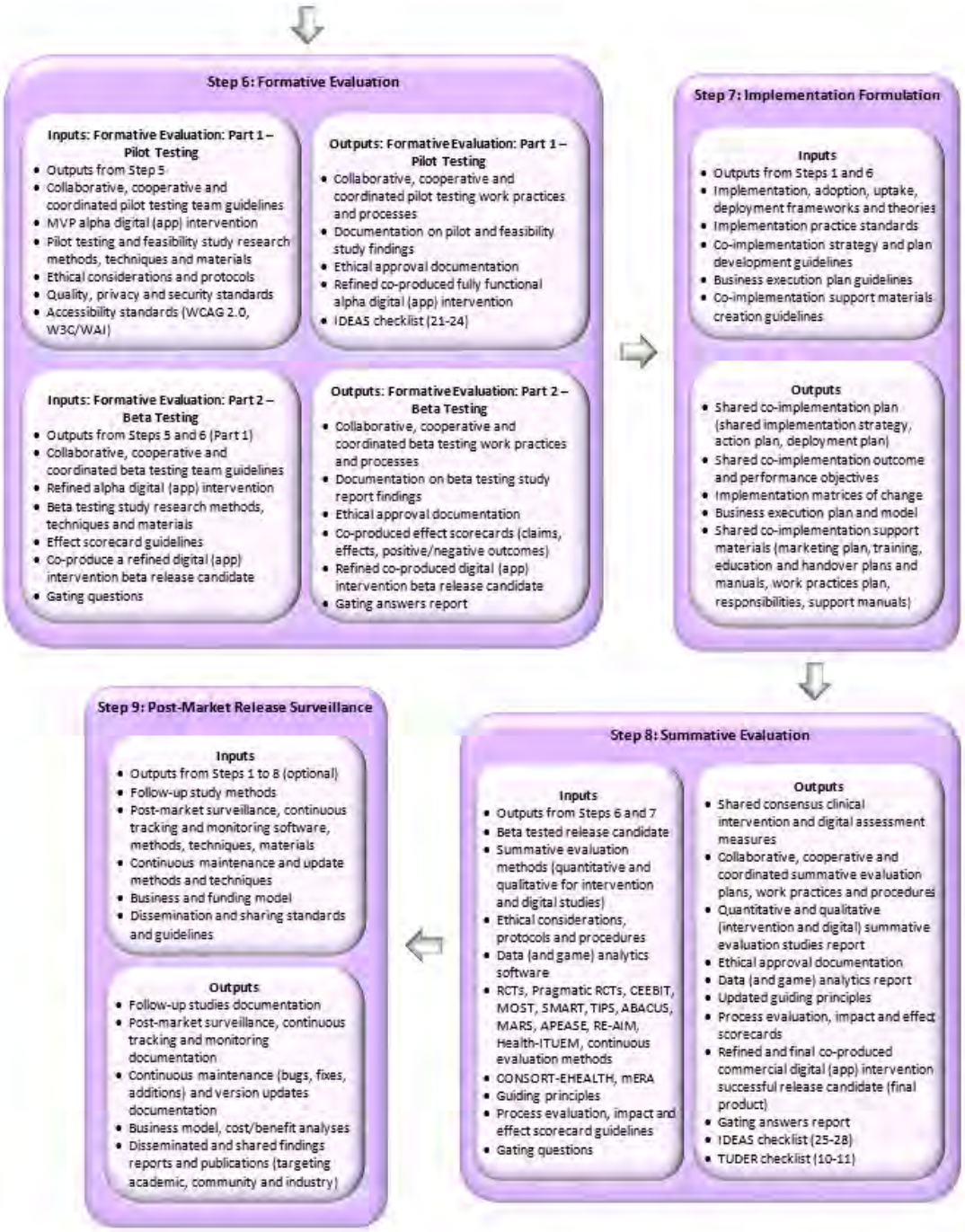



*Figure 6. 9: Common Design Artefact, Boundary Object and Supporting Method Themes and Subthemes across the Four Perspective Categories [Source: Researcher's own construction]*

*Table 6. 11: Nature of Inputs and Outputs at Multi/Interdisciplinary Process Steps across the Four Perspective Categories [Source: Researcher's own construction]*

| Process Step | Nature of Inputs into Step | Nature of Outputs produced from Step |
|---|---|---|
| **Step 1:** ***Team, Business and Project Formalisation*** | Input objects into Step 1 provide guidelines, procedures, protocols and templates for documenting the formalisation of the mHealth app's multi/ interdisciplinary team, business model, project, collaborative design, development and evaluation process plan, and partnership agreements. Guidelines are provided for the team to co-create a shared syntactic and semantic common knowledge base. | Output objects produced from Step 1 concern the formalisation of contracts, agreements and documentation regarding the multi/interdisciplinary team, business model, project, collaborative design, development and evaluation process plan, and established partnerships. The syntactic and semantic common knowledge base and formalised work practices supporting heterogeneous knowledge sharing and collaborative heteropraxial activities throughout the mHealth app development process. |
| **Step 2:** ***Problem Understanding*** | Input objects into Step 2 provide guidelines, recommendations, principles and methods for conducting activities and assessments applicable to explicating and understanding the health, target population and digital problem space. Additional input support materials (such as methods, ethical protocols and procedures) are employed for informing primary qualitative and quantitative research studies. Guidelines are provided for the team to co-define a shared understanding of the problem. | Output objects produced from Step 2 specify the project's selected health problem, target health behaviour and target population group, and assessments detail the associated context-relevant needs and demands. Models, checklists, reports and documentation are co-produced, outlining the team's shared co-definition and the initial building blocks of the project's problem space from both the health behavioural intervention and digital technology perspectives. |
| **Step 3:** ***Theoretical and Conceptual Solution Development*** | Input objects into Part 1 of Step 3 provide guidelines, recommendations and templates for specifying the project's theoretical base, comprising the mHealth intervention app's themes, scope, clinical and usage aims, performance and change objectives, business model and digital value map.<br><br>Input objects into Part 2 of Step 3 provide guidelines, recommendations, standards, codes of practice, frameworks, models, toolkits, taxonomies, principles and strategies for informing the co-creation of the project's conceptual base (on a theoretical level). Additional input support materials (such as methods, ethical protocols and procedures) are employed for informing primary qualitative and quantitative research studies. Guidelines are provided for the team to co-create high-level flow intervention and user maps, and to co-produce a common document detailing the shared vision of the project's theoretical and conceptual base. | Output objects produced from Part 1 of Step 3 specify the project's theoretical base, outlining the co-defined health behavioural outcomes, clinical and usage aims, performance and change objectives, business model and digital value map. Models, lists, matrices and reports are co-produced to support the team's shared understanding of the health behaviour change intervention app's theoretical base solution.<br><br>Output objects from Part 2 of Step 3 specify, describe and detail the selected theoretical frameworks and models, theory and evidence-based methods (BCTs), evidence-based standards and codes of practice, and the selected persuasive and gamification strategies. Lists, tables, matrices and models illustrate the translation of the selected methods, standards and strategies into practical strategy applications at the theoretical conceptual level. Additional high-level flow maps, checklists, reports and documentation are co-produced outlining the team's shared vision of the project's theoretical conceptual base solution. |
| **Step 4:** ***Instantiated Conceptual and Technological Solution Design*** | Input objects into Step 4 provide guidelines, frameworks, models, taxonomies, templates, methods and techniques for translating and operationalising the theoretical and conceptual solution (at a theoretical level) into a conceptual and technological design solution (at an instantiation level). Additional input support materials (such as methods, ethical protocols and procedures) are employed for informing primary qualitative and quantitative research studies. Guidelines are provided for the team to co-create low-fidelity conceptual design solutions, and to co-produce a co-design and co-development plan and document detailing the | Output objects from Step 4 outline, describe and detail the project's instantiated conceptual and technological design solution. Specification tables and documents detail the software instantiated strategies, principles, elements and techniques applicable to the intervention content (e.g. messages), BIT elements, technical characteristics, (intervention and user interaction) workflows, persuasive design features, and motivational frames. Additional collaborative diagrams, narratives, low-fidelity conceptual design solutions, design rationale, guiding principles, checklists, reports and documentation are co-produced outlining the team's shared co-design |

| | | |
|---|---|---|
| | project's conceptual and technological instantiated design solution. | and co-development plan of the instantiated conceptual and technological design solution. |
| **Step 5:**<br>***Instantiated Concrete and Material Solution Design*** | Input objects into Step 5 provide collaborative prototyping work practice and activity guidelines, methods, techniques, software and materials for the team to co-design and co-develop concrete and material design instantiations of the digital health behaviour change intervention app in various low-, middle- and high-fidelity prototype forms. Additional input support materials (such as methods, ethical protocols and procedures) are employed for informing primary qualitative and quantitative research studies. | Output objects from Step 5 are primarily a range of low-, middle- and high-fidelity prototype versions of the concrete and material digital health behaviour change intervention app. Secondary objects document the team's collaborative, cooperative and coordinated co-design and co-development work practices, processes and heteropraxial design activities. Shared (common) syntactic, semantic and pragmatic output objects enable and support the creation of the primary and secondary artefacts. Additional checklists, reports and documentation concerning the iterative concrete prototyping design instantiation process are co-produced. The final key output from Step 5 is a co-designed and co-developed MVP (near fully functional) alpha app prototype. |
| **Step 6:**<br>***Formative Evaluation*** | Input objects into Part 1 of Step 6 provide collaborative, cooperative and coordinated guidelines, methods and techniques for the team to conduct pilot testing and feasibility study research on the MVP alpha app prototype. Additional input support materials (such as methods, ethical protocols and procedures, quality, privacy and security standards, accessibility standards) are employed and referenced for informing primary qualitative and quantitative formative evaluation studies.<br><br>Input objects into Part 2 of Step 6 provide collaborative, cooperative and coordinated guidelines, methods and techniques for the team to conduct beta testing studies on the fully functional alpha app. Additional input support materials (such as methods, ethical protocols and procedures, effect scorecards) are employed for informing primary qualitative and quantitative formative evaluation studies. | Output objects from Part 1 of Step 6 document and detail the study designs, ethics, data collections, data analyses and findings from the team's pilot testing and feasibility studies conducted on the MVP alpha app prototype. Additional documentation is co-produced detailing any refinements and changes made to the alpha app version(s) as a result of the pilot testing studies. The key output from Step 6 is a co-produced fully functional health behaviour change intervention alpha app.<br><br>Output objects from Part 2 of Step 6 document and detail the study designs, ethics, data collections, data analyses and findings from the team's beta testing studies conducted on the alpha app. Additional documentation is co-produced detailing any refinements and changes made to the alpha app version(s) as a result of the beta testing studies. The key output from Step 6 is a further refined, co-produced health behaviour change intervention app as a beta release candidate. |
| **Step 7:**<br>***Implementation Formulation*** | Input objects into Step 7 provide theories, frameworks, standards and guidelines for the team to collaboratively develop a co-implementation strategy, recruitment plan, action plan, deployment plan and business execution plan. Additional inputs and guidelines are employed to co-produce co-implementation support materials. | Output objects from Step 7 document and detail the team's co-implementation plan, comprising the shared implementation strategy, recruitment plan, action plan, deployment plan and business execution plan. Additional shared co-implementation support materials are co-produced. |
| **Step 8:**<br>***Summative Evaluation*** | Input objects into Step 8 provide collaborative, cooperative and coordinated guidelines, methods and techniques for the team to conduct summative evaluation studies on the beta release candidate. Additional input support materials (such as frameworks, models, criteria, checklists, software, and ethical protocols and procedures) are employed and referenced for informing primary qualitative and quantitative summative evaluation studies. | Output objects from Step 8 document and detail the team's shared collaborative, cooperative and coordinated summative evaluation study designs, ethics, assessment measures, plans, work practices and procedures, data analyses and findings on the beta release candidate. Additional documentation, checklists and reports are co-produced detailing any refinements and changes made to the beta release candidate app as a result of the summative evaluation studies. The key output from Step 8 is a refined co-produced commercial consumer app as a successful release candidate (final product). |

| | | |
|---|---|---|
| **Step 9:**<br>***Post-Market Release Surveillance*** | Input objects into Step 9 provide guidelines, methods, techniques, standards and materials for supporting the team in conducting post-market surveillance on the successful release app candidate (final product). Additional input support materials (such as software) are utilised to carry out continuous tracking, monitoring, maintenance and cost/benefit analyses during the lifespan of the commercially released consumer app. | Output objects from Step 9 document and detail all of the post-market release surveillance activities, including follow-up studies, continuous tracking and monitoring, continuous maintenance and updates, and the reviews, analyses and revisions of the project's business and funding models. Additional reports, publications and documentation are disseminated and shared across academic, community and industry spheres. |

### 6.5.6 Knowledge Boundaries

Design artefacts, boundary objects and supporting methods facilitate and mediate the transfer, translation and transformation of knowledge across syntactic, semantic and pragmatic knowledge boundaries, respectively. The diversity of knowledge, expertise and skills required for designing, developing and evaluating mHealth physical activity behaviour change intervention apps are "localised, embedded and invested in practice" across a heterogeneity of practice communities and disciplines (Carlile, 2002, p.442). Within the shared boundary space, knowledge is both a source and a barrier to the multi/interdisciplinary design, development and evaluation of innovative mHealth (promotion) behaviour change intervention app solutions. Paradoxically, knowledge boundaries become both a necessity (in that they respect and differentiate diverse knowledge contributions) and a critical challenge (in that they need to be addressed and overcome) (Carlile, 2002; 2004).

A critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed the majority of approaches as latently and explicitly arguing for the transfer, translation and transformation of knowledge across heterogeneous community boundaries as a necessary and integral requirement for improving the collaborative design of mHealth behaviour change intervention apps. Approach #8, for instance, argues that a diversity of knowledge, expertise, skill and practice activity contributions prompts the "generation of more highly divergent ideas" and app prototype instantiations, which has shown to lead to more creative, innovative and efficacious final output mHealth behaviour change intervention app design solutions (Mummah, et al., 2016, p.5). Approach #14 emphasises that "building on [the] complementary strengths and different types of expertise" requires a "common knowledge base" with common languages (at a syntactic level), common meanings (at a semantic level) and common interests (at a pragmatic level) first be established, respected and adhered to by all of the collaborating heterogeneous team members (Carvalho, Jun and Mitchell, 2017, p.8). This further requires the differences in worldview perspectives, language (jargon) usage,

interpretations of meaning, goals and interests (or values) be explicitly articulated and acknowledged by all of the involved multi/interdisciplinary collaborating team members.

In terms of team management and knowledge related objects, Approach #2 provides a valuable contribution in advocating for mediating objects (such as team, business and project documentation) that clearly identify, organise and coordinate the different roles, responsibilities and decision-making powers of each collaborating multi/interdisciplinary team member. Approach #2 also emphasises the use of mediating objects (such as team, business and project documentation) that clearly outline how the diverse knowledge, expertise and skill contributions offered by each team member of a collaborating multi/interdisciplinary team are incorporated and coordinated in the heteropraxial process steps and activities. These (team, business and project) artefacts and objects are created and formalised in the first step of the multi/interdisciplinary process (as specified in Figure 6.8 and Table 6.11), and essentially relate to themes on roles, responsibilities, decision-making powers, and negotiation and conflict resolution processes which feed into and operate at across all three knowledge boundaries.

***Syntactic Knowledge Boundary***

At a syntactic knowledge level, differences in the representation of knowledge and how language and terminology is stored (or classified), processed, transferred and retrieved should be explicitly articulated, communicated and discussed by the participating multi/ interdisciplinary collaborating team members. A critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed several common syntactic knowledge object subthemes. These include: standardised language (lingua franca) artefacts; co-definitions; common glossaries (of key concepts and terms); shared ontologies; the CALO-RE and BCTT v1 coding taxonomies; the unified DHI Taxonomy; the Behavioural Theories Toolbox; the Toolkit of Behavioural Strategies; the TBCM development taxonomy; the PSDM principles; the TDF; the BCW; the COM-B Model; and other common lexicons and shared taxonomies and ontologies. These knowledge objects (and their acronyms) were identified and discussed in Chapters 3 and 4, and under Sections 6.5.3 and 6.5.5. Moreover, Approaches #17 and #19 point out that since multi/interdisciplinary collaborating team members "come from different fields" and "often speak different jargon", the creation and utilisation of shared syntactic objects should provide a common language and vocabulary that "bridg[es] the language gap[s] and barriers… between the different fields involved in the [mHealth app] development process" (Blanson Henkemans, et al., 2015, p.54-55).

***Semantic Knowledge Boundary***

In transitioning from a syntactic to a semantic knowledge level, artefacts and objects facilitate and mediate translations concerning the differences and dependencies in collaborating team members' knowledge, activities and interpretations of meaning. Essentially, shared and common semantic objects allow heterogeneous team members with ways of representing and learning about differences and dependencies in knowledge, expertise and skill contributions. A critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed a common theme concerning the ways heterogeneous practice communities assign different interpretations of meaning to the same terminology. Common semantic *interpretively flexible terminological* subtheme examples include, namely: "usability"; "acceptance" (or "acceptability"); "adherence"; "user experience"; "engagement"; "persuasiveness" (or "persuadability"); "satisfaction"; "enjoyment" (or "enjoyable"); "motivation" (or "motivating"); and "convincing".

Notably, considering that the knowledge levels build on one another, and *shared standardised language objects* created on the syntactic level can be referenced by multi/interdisciplinary collaborating team members in supporting the clarification of common meanings on a semantic level. Approach #19 emphasises that a failure to differentiate between interpretations of meaning can "lead to misunderstandings" that can hinder multi/interdisciplinary team members' communication, collaboration, cooperation and coordination efforts if not managed accordingly, ultimately negatively affecting the design, development and subsequent effectiveness potential, of the mHealth app consumer product output (Blanson Henkemans, et al., 2015, p.54).

The critical cross-comparative overview of the thematic and comparative findings across the four perspective categories also revealed artefacts such as *standardised processes and methods* as a key semantic object theme. Common subthemes falling under this semantic theme include: shared processes; shared methods; co-design processes and methods; co-development processes and methods; co-implementation processes and methods; co-evaluation processes and methods; shared strategy plans; shared collaborative methods; and a shared co-created mHealth behaviour change intervention app design, development and evaluation process (as identified in Figure 6.8 and Table 6.11). Approach #16 also discussed the use of "entire cooperative frameworks" that outline the informatic needs, work routines, practices and

processes of multi/interdisciplinary collaborating teams (Scandurra, Hägglund and Koch, 2008a, p.560).

Associated with the theme on shared processes and methods is a theme concerning the creation of *common meanings*, which attempts to address and bridge differences in interpretations of meaning between heterogeneous collaborating team members. The critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed several semantic knowledge object subthemes that support the creation of common meanings. These include: shared co-understandings (of the mutual problem space); shared co-visions (of the joint solution space); shared co-implementation strategies and action plans; shared co-evaluation strategies and action plans; and notably, Approach #16 highlights the importance of creating "a common picture of what the [mHealth app]… should be" (Scandurra, Hägglund and Koch, 2008a, p.562).

Additional semantic knowledge objects themes and subthemes include: co-created formalised and standardised forms; templates; documentation; standardised guidelines (such as CONSORT-EHEALTH); standardised checklists (such as mERA); standardised codes of practice (such as the British Standards Institution Code of Practice for Health and Wellbeing Apps); accessibility standards (such as WCAG 2.0, W3C/WAI); and quality, privacy and security standards.

***Pragmatic Knowledge Boundary***

In progressing from a semantic to a pragmatic knowledge level, design artefacts and boundary objects help facilitate and mediate the transformation and generation of new multi- and interdisciplinary knowledge. For knowledge to be transformed and newly created, multi/ interdisciplinary collaborating team members need to actively engage in communications, practices and processes that enable negotiations and resolutions around differences in and conflicts of interest and goals pertaining to the heteropraxial design, development and evaluation of mHealth physical activity behaviour change intervention apps. The chief aim at a pragmatic knowledge level is for multi/interdisciplinary collaborating team members to engage in negotiations and decision-making processes with the intention of creating common interests and common goals.

A critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed a common and predominant *pragmatic prototype design*

*boundary object* theme concerned with helping multi/interdisciplinary collaborating teams achieve common goals and interests, specifically in terms of the teams' creation and iterative refinement of various low-, medium- and high-fidelity mHealth app prototypes. Common *low-fidelity* subthemes falling under the pragmatic prototype design boundary object theme include: papers sketches; thumbnail sketches; user interface screen design mock-ups; storyboards; intervention and component flow mock-ups; paper-based wireframes; and other paper and creative material prototypes (such as objects made from colourful moulding putty, sticky notes, beads, shapes, fluffy pom-poms, beads, ribbons, picture and paper cut-outs, et cetera). Common *medium-fidelity* subthemes falling under the pragmatic prototype design boundary object theme include: software-based (CAD) screen mock-ups; software-based (CAD) wireframes; 2D simulations; 3D simulations; and basic-feature and core-functionality clickable and interactive software-based (CAD) prototypes. Common *high-fidelity* subthemes falling under the pragmatic prototype design boundary object theme generally include functional, working and interactive software-based app simulations and smartphone-based app prototypes. Other pragmatic prototype design boundary object subthemes, which can be referred at different levels of fidelity, include: design scenarios; design rationale; use case scenarios; use case diagrams; common concept maps; personas; requirements and claims specification cards; and communal pictures.

Essentially, pragmatic prototype design boundary objects provide multi/interdisciplinary collaborating team members with concrete and tangible artefact materials that can be used to support and facilitate communications and negotiations around different, and potentially conflicting, interests and goals regarding a given mHealth app's design, development and evaluation. In addition, pragmatic prototype design boundary objects provide a concrete and tangible way for multi/interdisciplinary collaborating team members to engage in perspective-making and perspective-taking mental processes, which over time, fosters new insights and understandings. Approach #16 describes these mental processes as "triggering innovative thinking" and the joint creation of new transformative knowledge and new mHealth behaviour change intervention app design solutions (Scandurra, Hägglund and Koch, 2008a, p.565).

Furthermore, in terms of intervention content, teamwork and process procedure, other pragmatic boundary object subthemes include: logic modelling and flow diagrams; work boundary maps (outlining the collaborative, cooperative and coordinated heteropraxial design activities, and the heterogeneous knowledge, expertise and skill contributions); and process

maps (such as a diagrammatic representation of the shared co-created multi/interdisciplinary process plan). Lastly, a common pragmatic knowledge theme interwoven in the above-mentioned themes concerns *politics and power relations (dynamics)*, specifically concerning multi/interdisciplinary team member decision-making powers and the creation and use of guidelines for negotiation, conflict resolution, and decision-making practices and processes.

Table 6.12 summarises the main knowledge themes and subthemes identified during the critical cross-comparative thematic overview across the four perspective categories, categorised in terms of the three knowledge boundaries, knowledge capabilities, knowledge boundary aims, and associated knowledge objects for each knowledge boundary.

*Table 6. 12: Common Knowledge Boundary and Knowledge Object Themes and Subthemes across the Four Perspective Categories [Source: Researcher's own construction]*

| Knowledge Boundary | Knowledge Capability | Knowledge Boundary Aim(s) | Knowledge Boundary Objects |
|---|---|---|---|
| **Syntactic** | • Transfer<br>• Information processing | • Common language | • Standardised language (*lingua franca*) and shared glossaries<br>• Shared co-definitions<br>• Shared ontologies<br>• Shared taxonomies<br>• Shared toolboxes<br>• Standardised principles |
| **Semantic** | • Translation<br>• Interpretation of meaning | • Common meanings<br>• Coordinated, cooperative and collaborative practices | • Interpretively flexible terminology<br>• Shared co-understandings<br>• Shared co-visions<br>• Shared co-created, standardised processes<br>• Shared frameworks and models<br>• Standardised methods<br>• Shared plans and strategies<br>• Standardised forms and templates<br>• Shared co-created documentation<br>• Standardised guidelines (e.g. WHO physical activity guidelines) |
| **Pragmatic** | • Transformation<br>• Conflicts of interest<br>• New knowledge generation | • Common interests<br>• Common goals<br>• Common values<br>• Politics and power relations/dynamics<br>• Negotiations, decision-making, conflict resolution<br>• Innovation | • Collaboratively co-produced low-, medium- and high-fidelity app prototypes<br>• Perspective-making and perspective-taking supporting objects<br>• Shared diagrams, workflows and maps<br>• Shared collaborative and cooperative process plans (incl. power relations, negotiation, decision-making and conflict resolution processes and practices) |

### 6.5.7 Limitations and Lessons Learned

The critical cross-comparative overview of the thematic and comparative findings across the four perspective categories revealed several limitations and knowledge gaps in all twenty of the selected multi- and interdisciplinary digital health intervention approaches, yet also yielded some important insights and lessons learned. Ten common limitation and lesson learned themes were identified across all four of the perspective categories. Notably, this is not an exhaustive list, but instead aims to identify the main valuable and relevant cross-comparative findings.

Firstly, with regard to the *digital platform and health behaviour intervention contexts*, only eight of the twenty multi- and interdisciplinary approaches are particularised to the mobile app and physical activity behaviour change intervention contexts specifically. The remaining twelve approaches, while limited in their mobile app and physical activity context contributions, still offer other valuable insights in terms of technological and health promotion intervention design, development and evaluation. A second contextual theme relates to the *dual intra-interpersonal socioecological level of health promotion intervention delivery*. Fourteen of the twenty multi- and interdisciplinary approaches are orientated towards delivering health behaviour change interventions at the dual intra-interpersonal socioecological level, whereas six approaches are limited in their broader, more complex socioecological level orientation (for example, targeting the organisational or societal level, Chapter 3, Figure 3.2). The first and second contextual themes link with a third contextual theme, which concerns the lessons learned from several multi- and interdisciplinary approach contextual applications to specific real-world *commercially released and research-based mHealth physical activity behaviour change intervention consumer apps*. Examples of these apps include: *MyFitnessPal*; *HelpMeDot!*; *TODAY*; *Puzzle Walk*; *30 Day Fitness Challenge*; *Step Counter*; *Nike+ Running*; *Fitocracy*; and *Endomondo*; amongst others.

A common fourth theme, associated with the first, second and third themes, relates to whether the multi- and interdisciplinary approaches provide intervention designers and developers with sufficient *practical guidance for translating, operationalising and instantiating intervention strategies (components) and BCTs into technical interactive mobile app design features*. Only seven of the twenty multi- and interdisciplinary approaches offer app design feature operationalisation and instantiation guidance, of which only two approaches offer BIT element translation, operationalisation and instantiation guidance specifically. The other thirteen approaches, in comparison, are limited in their failure to support technical and design feature

translation practices. This is a noteworthy weakness of these thirteen approaches considering the essential and imperative role materialisation and instantiation plays in designing, developing and evaluating effective mHealth physical activity behaviour change apps. This translation, operationalisation and instantiation guidance knowledge gap was also discussed in Chapter 4, Section 4.4.2.

The fifth common limitation theme concerns the *time and resource demands* required by the twenty multi- and interdisciplinary approaches across the four perspective categories. While all twenty of the multi- and interdisciplinary approaches across the four perspective categories require a range and diversity of resources to carry out their respective process steps and activities, a noteworthy limitation and weakness is that a significant proportion of them (fifteen) are comparably more time and resource intensive than their respective category counterparts. This resource limitation theme is important considering the various cost and operational constraints faced in the rapidly evolving mHealth behaviour change app intervention arena (touched on in Chapter 4, Section 4.4.3.1). Furthermore, in keeping with the resource demands theme, a sixth common limitation theme is that all twenty multi/interdisciplinary approaches *require and implicitly assume that all of the collaborating team members possess sufficient specialist knowledge, expertise and skills to interpret, understand and apply all of the steps and activities presented in their respective processes*. This implies a need for considerable past experience and substantial tacit knowledge and understanding, which in turn discourages and hampers the adoption, use and application of the twenty approaches by inexperienced, untrained and amateur health (promotion) behaviour change app intervention designers and developers.

In terms of the process nature of the multi- and interdisciplinary approaches, a seventh key common lesson learned across all four of the perspective categories emphasised an *iterative and flexible process nature* theme. Several approaches repeatedly noted certain process qualities, including systematic, non-linear, theory-based, evidence-based, continuous, cumulative, and reflective/reflexive descriptive characteristics. Notably though, as a limitation, only a handful of the analysed approaches emphasised the importance of an agile (or rapidly agile), dynamic and cyclical (feedback loop) process to mHealth intervention app design, development and evaluation. This is a key weakness of several of the approaches considering that the mobile device and app industries and environments are relatively dynamic and evolutionary, and are continuously advancing and expanding, which requires that mHealth apps

be continuously improved and updated over time, thus requiring faster and more agile approaches to mHealth behaviour change intervention app design, development and evaluation.

In terms of process steps and activities, the eight theme was a contribution and valuable lesson learned by Approach #12. Approach #12 is the only approach of the selected twenty secondary dataset that incorporated *alpha testing and beta testing practices* in the multi/interdisciplinary process. The other nineteen approaches, in contrast, are limited in their failure to recognise and/or harness the benefits associated with alpha testing and beta testing methods. Notably though, a distinct limitation and lost opportunity for all twenty of the selected multi- and interdisciplinary approaches is their failure to recognise the value offered by adopting delta testing methods, practices and processes; which are particularly well suited to the mHealth (physical activity) behaviour change intervention app design, development and evaluation environment. A description of delta testing and its advantages and accruing benefits are discussed in Subsection 6.4.2.7 (Appendix I).

In keeping with the evaluation reference, a ninth common theme – that encompasses both a limitation and lesson learned – concerns the approaches' summative evaluation methods. Of the four perspective categories, the *health sciences approaches favour traditional randomised controlled trials (RCTs) as summative evaluation methods* considerably more than the information systems and technology, partnership and integrative approaches. This is a notable limitation in that there are several legitimate criticisms concerning the inappropriate, incompatible and impractical sole use of RCTs for evaluation purposes in the mHealth behaviour change intervention app arena. These key criticisms are discussed in Subsection 6.4.1.7 (Appendix I) and touched on in Chapter 4 (Subsection 4.4.3.1). To counter this limitation, several approaches in the other three perspective categories, and particularly the approaches in the Information Systems and Technology Perspective category, offer alternative qualitative and quantitative summative evaluation methods. Common key *alternative and adaptive summative evaluation methods, tools and instruments* include pragmatic RCTs, CEEBIT, MOST, SMART, TIPS, ABACUS, MARS, uMARS, APEASE, RE-AIM, Health-ITUEM, and continuous evaluation methods. These are discussed in more detail in Subsections 6.4.2.4, 6.4.2.5 and 6.4.2.7 (Appendix I) and in Chapter 4 (Subsection 4.4.2).

A tenth limitation theme identified across all twenty of the multi- and interdisciplinary approaches in the four perspective categories is a *failure to recognise and/or discuss any concepts and constructs regarding community of practice theory, boundary object theory and*

*knowledge boundary theory*. On the one hand, this demonstrates a noteworthy knowledge gap in the existing knowledge base. On the other hand, this *confirms and verifies that the proposed boundary object view (the tri-composite theoretical framework) offers a novel contribution to the current knowledge base* concerning the relatively "young" (Mummah, et al., 2016, p.1) and "emerging interdisciplinary" mHealth (physical activity) behaviour change intervention app arena (Taj, Klein and van Halteren, 2019, p.1). The newly proposed boundary object view (tri-composite theoretical framework) is valuable in its novel contribution to the knowledge base, yet presents a somewhat challenge in identifying and extracting key community of practice, boundary object and knowledge boundary themes in existing multi- and interdisciplinary digital health intervention development approaches. For the most part, the community of practice, boundary object and knowledge boundary themes and subthemes identified and discussed throughout the critical thematic and comparative analysis findings have been latent and implicit since none of the twenty approaches explicitly acknowledged any of the three process kernel theories.

Overall, in summarising the limitations and lessons learned from the critical cross-comparative thematic review, ten common key themes have been identified and discussed. A summary of these themes are presented in Table 6.13. On a final note regarding limitations, it is acknowledged that the findings discussed in this critical thematic and comparative analysis exclude potentially informative and insightful multi- and interdisciplinary approaches that were published after the secondary dataset had been selected and after the critical analysis report findings had been written up. Examples of more recent multi- and interdisciplinary digital health intervention development approaches include Sucala, et al.'s (2020) *Iterative, Interdisciplinary, Collaborative Framework for Developing and Evaluating Digital (Health) Behaviour Change Interventions*, Kowatsch, et al.'s (2019) *Design and Evaluation Framework for Digital Health Interventions*, and Blandford's (2019b) *Integrated Development Lifecycle for Digital Health Technologies*. In light of this acknowledged limitation, boundary object view relevant and valuable themes and subthemes that are identified and discussed in these three above-mentioned literature publications are later incorporated into the interdisciplinary framework artefact's development and revised refinement in Chapter 7 and Chapter 10.

*Table 6. 13: Common Limitation and Lessons Learned Themes across the Four Perspective Categories [Source: Researcher's own construction]*

| No. | Limitation and/or Lesson Learned Theme |
|---|---|
| **1.** | ***Limitation:*** Somewhat limited insights pertaining to digital platform (mobile app) and health behaviour change intervention (physical activity) contexts. |
| **2.** | ***Limitation:*** Somewhat limited targeted orientation towards the dual intra-interpersonal socioecological level of health promotion intervention delivery. |
| **3.** | ***Lesson learned:*** Multi- and interdisciplinary approach contextual applications to specific real-world commercial and research-based mHealth physical activity behaviour change intervention consumer apps. |
| **4.** | ***Limitation:*** Lack of practical guidance for translating, operationalising and instantiating intervention strategies (components) and BCTs into technical interactive mobile app design features. |
| **5.** | ***Limitation:*** Time and resource demands to carry out multi- and interdisciplinary approach processes. |
| **6.** | ***Limitation:*** The requirement and implicit assumption that all of the multi/ interdisciplinary collaborating team members possess sufficient knowledge, expertise and skills to interpret and apply the process steps and activities. |
| **7.** | ***Lesson learned:*** Multi- and interdisciplinary collaborative design, development and evaluation processes should be iterative and flexible in nature. |
| **8.** | ***Limitation:*** Lack of recognition and adoption of delta testing methods.<br>***Lesson learned:*** The value in employing alpha testing and beta testing methods. |
| **9.** | ***Limitation:*** A health sciences biased preference for traditional RCTs.<br>***Lesson learned:*** Adaptive summative evaluation methods, tools and instruments. |
| **10.** | ***Limitation:*** Lack of recognition for the value of community of practice, boundary object and knowledge boundary theory; requiring latent seeking thematic analysis.<br>***Lesson learned:*** Verification that the proposed boundary object view offers a novel perspective and contribution to the knowledge base. |

## 6.6 Conclusion

This chapter contributes to answering the third research sub-question by conducting a critical thematic and comparative theoretical analysis on a selected secondary dataset of twenty multi- and interdisciplinary digital health intervention development approaches, to identify and extract the main boundary object view themes and subthemes necessary and relevant to inform the development of the interdisciplinary framework artefact solution (Chapter 7). The chapter started by positioning the critical theoretical analysis within the research project's DSR methodology, after which the importance of theorising and theory building was presented, followed by an articulation of the implicit assumptions and philosophical underpinnings of the critical theoretical analysis.

The theorising research approach used to conduct the critical theoretical analysis was then introduced and discussed, justifying the adoption of a novel hybrid cognitive reasoning strategy together with Weick's (1989) three-component theorising approach. The first component, *problem formulation*, allowed the researcher to establish an "intimate familiarity with the problem", by: (1) outlining how Chapters 1 to 5 have contributed to elucidating the problem; (2) explicitly stating implicit assumptions; (3) defining key problem terminology; and (4) identifying the perspectives adopted by the researcher in framing and structuring the problem (and solution). The second component, *thought trials*, described the role of trial-and-error imaginary experiments with disciplined imagination, creativity, intuition and theory concepts to analyse and build theory. To guide the thought trials during the critical analysis, the thematic and comparative theorising approach was outlined, and the importance of heterogeneity in generating conjectures and process and product kernel theories was discussed. The third component, *selection criteria*, provided the researcher with judgement and sensemaking tools – including a hermeneutic search and acquisition approach, a selection criteria template, and a template criteria – to frame the secondary data collection and critical analysis processes.

The critical thematic and comparative theoretical analysis was then conducted on the twenty selected multi- and interdisciplinary digital health intervention development approaches in each of the four Health Sciences, Information Systems and Technology, Partnership and Integrative Perspective categories, and the findings were written up. Thereafter, a comprehensive and consolidating cross-comparative critical analysis was performed on the overall findings across the four perspective categories, to identify the main common themes and subthemes pertinent to the boundary object view and new artefact contribution. The main common thematic component findings covered the: (1) *aims and context*; (2) *actors and communities of practice*; (3) *perspectives, underlying theories, models, tools and existing approaches*; (4) *nature of processes and process steps and activities*; (5) *design artefacts, boundary objects and supporting methods*; (6) *knowledge boundaries*; and (7) *limitations and lessons learned*. Table 6.14 and Figure 6.10 provide an overview of the theorising research approach and the main common theme findings, respectively. The findings are used to inform the development of a conceptual interdisciplinary framework for guiding the design of mHealth intervention apps for physical activity behaviour change (Chapter 7).

*Table 6. 14: Theorising Research Approach Overview [Source: Researcher's own construction]*

| **Theorising Research Approach** | |
|---|---|
| **Hybrid Cognitive Reasoning Strategy** | Using a novel hybrid abductive, deductive and top-down inductive cognitive reasoning strategy to conduct the critical analysis |
| **Weick's (1989) Theorising Approach** | Applying Weick's (1989) three-component theorising approach to guide the critical analysis process (Figure 6.2) |
| **Weick's (1989) Theorising Approach** | |
| **Component 1:** ***Problem Formulation*** | Establishing an "intimate familiarity" with the artificial DSR problem because "problem formulation and theory building go hand in hand" (Figure 6.3) |
| | • Research chapters elucidating problem (Table 6.1)<br>• Explicitly articulating implicit assumptions (Box 6.1)<br>• Defining key problem (and solution) terminology (Table 6.2)<br>• Perspectives framing the problem (and solution) |
| **Component 2:** ***Thought Trials*** | Using trial-and-error imaginary experiments with disciplined imagination, creativity, intuition and theory concepts to analyse and build theory. Applying heterogeneity in generating conjectures and selecting process and product kernel theories (Figure 6.5) |
| | *Process kernel theories:* community of practice theory, boundary object theory and knowledge boundary theory (Chapter 5) |
| | *Product kernel theories:* four perspective categories (health sciences, information systems and technology, partnership, integrative) (Figure 6.4) |
| | A thematic and comparative theorising approach to conducting thought trials and the critical analysis (Table 6.3) |
| **Component 3:** ***Selection Criteria*** | Using judgement and sensemaking tools to select a secondary dataset and conduct the critical thematic and comparative theoretical analysis (Figure 6.6) |
| | Hermeneutic search and acquisition approach, including search strategies (Box 6.2) and reading and acquisition techniques (Box 6.3) |
| | Selection criteria template (Table 6.4) |
| | Template criteria (Table 6.5) |
| | Summary of twenty selected multi/interdisciplinary approaches (Table 6.6) |

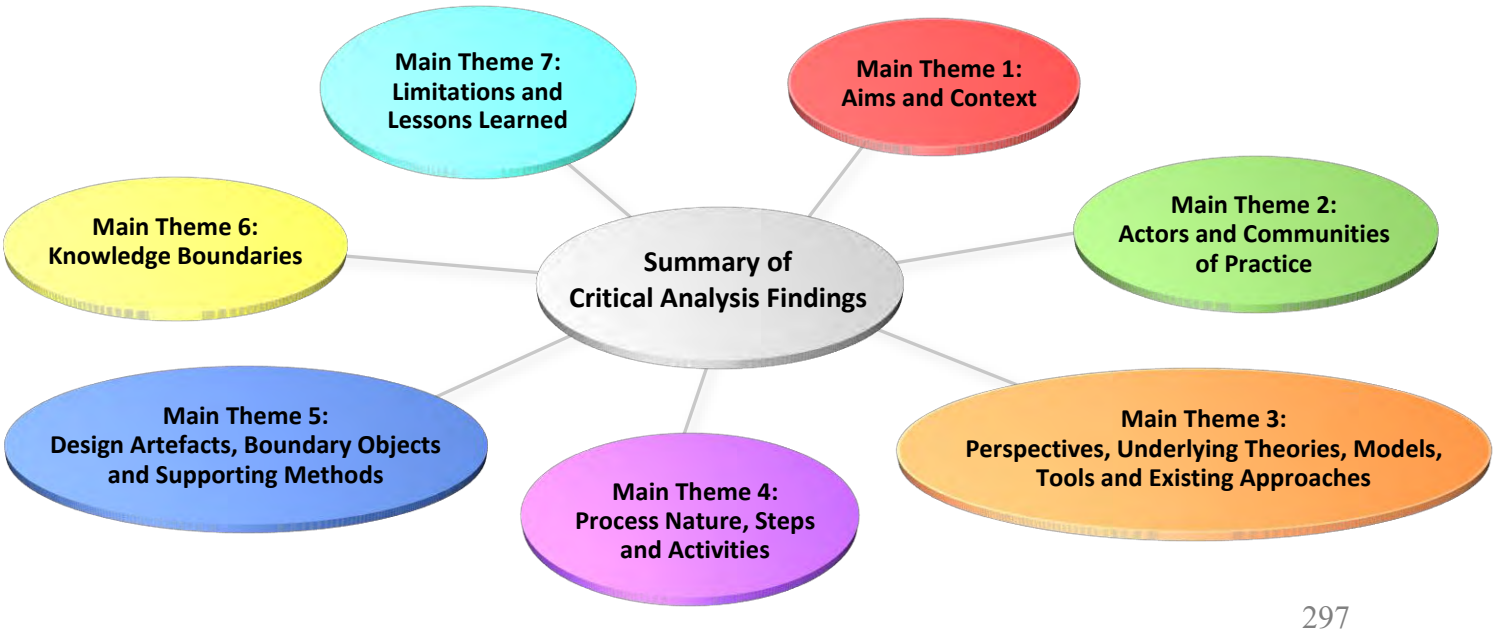




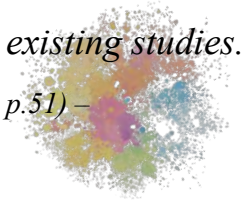

*Figure 6. 10: Main Common Theme Findings [Source: Researcher's own construction]*

# Chapter 7

# A Proposed Framework for Guiding the Interdisciplinary Collaborative Design of mHealth Intervention Apps for Physical Activity Behaviour Change

*Conceptual frameworks can be developed and constructed through a process of qualitative analysis [where] sources of data consist of many discipline-orientated theories that become the empirical data [and] from multidisciplinary bodies of knowledge, metasynthesis, a systematic synthesis of findings… which is both hermeneutic and comparative in nature, [allows] the researcher to expand our interpretation[s] beyond existing studies.*

*– Jabareen (2009, p.51) –*



## 7.1 Introduction

Designing effective mHealth physical activity behaviour change intervention apps targeting the dual intra-interpersonal socioecological levels requires a heterogeneity of knowledge, expertise and skill contributions from a diversity of practice communities. Artefacts and boundary objects can be employed, utilised and created by interdisciplinary teams to guide and support heteropraxial activities and knowledge sharing practices during the collaborative design, development and evaluation process, resulting in more innovative and effective mHealth intervention app product design solutions. A conceptual framework, framed by the boundary object view, is proposed for guiding and supporting the interdisciplinary design of mHealth intervention apps for physical activity behaviour change. The thematic findings from the critical theoretical analysis on twenty existing multi- and interdisciplinary digital health intervention development approaches informs the development of the framework. The Interdisciplinary mHealth App Design Framework's four main themes include the *"actors"*, *"process"*, *"boundary objects and supporting artefacts"*, and *"knowledge"*, and the two supplementary supporting themes concern the *"project boundary"* and *"outcomes"*.

This chapter first introduces the overall structure and main components of the proposed Interdisciplinary mHealth App Design Framework. Thereafter, the critical subcomponents and comprising elements of each component are discussed in detail, and the complex and intricate pragmatic symbolic interactionist and sociomaterial entanglement relationships between the components are described. The high-level relationships between the main components are then clarified, after which the limitations of the proposed framework are presented. Lastly, it is concluded that, in order to demonstrate the quality and trustworthiness of the proposed framework, and further particularise its significance and applicability to the physical activity promotion and mHealth app context, it is necessary to evaluate the framework with experienced knowledge experts from a heterogeneity of relevant disciplinary backgrounds.

The main aim of this chapter is to develop and detail the proposed conceptual framework. As illustrated in Figure 7.1, constructing a framework artefact falls within Step 3 ("artefact development") of the study's DSRM (outlined in Chapter 2). This chapter contributes to answering the third research sub-question: *"How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*.

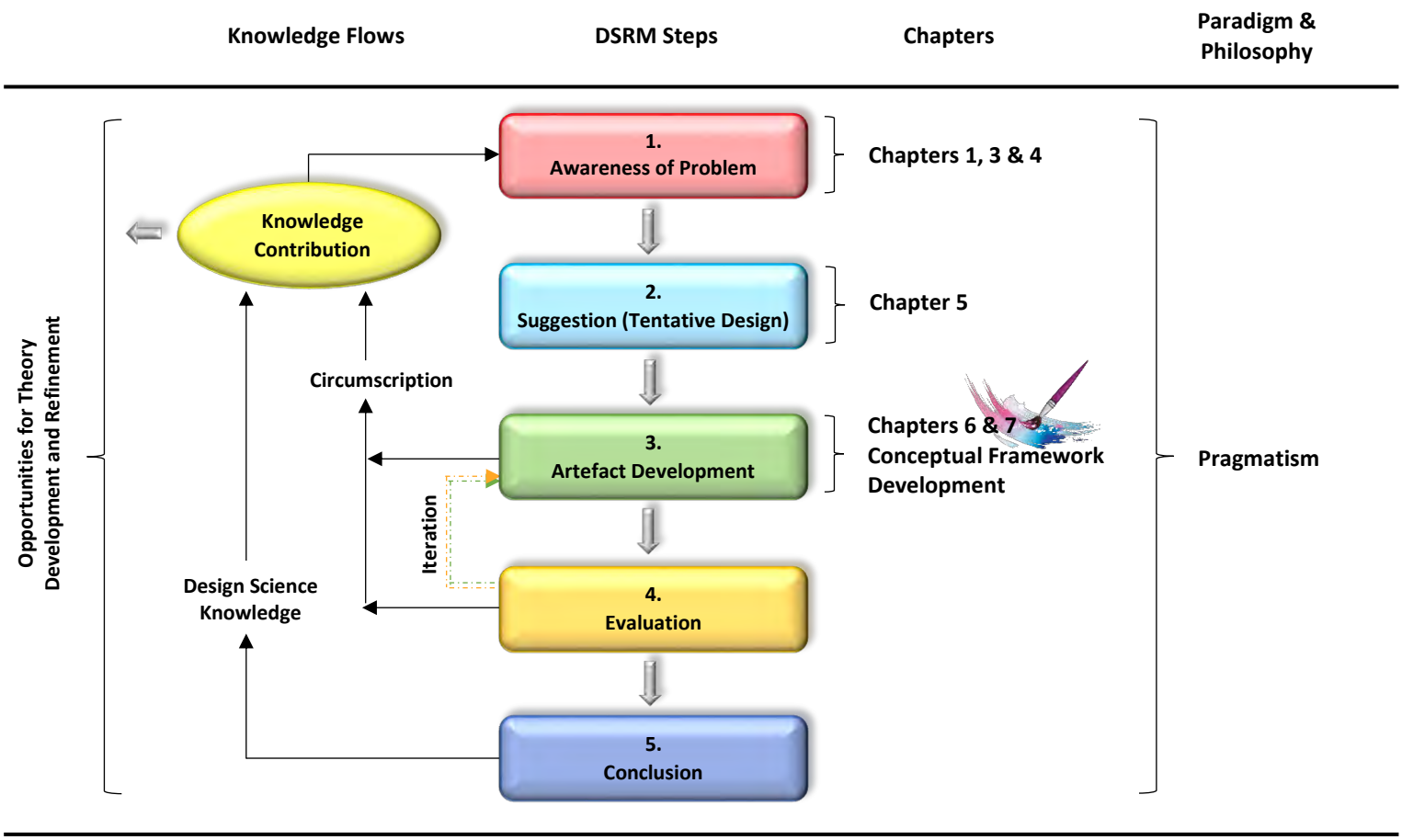



*Figure 7. 1: DSRM: Artefact Development: Developing a Proposed Framework [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 7.2 A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change

This section describes and diagrammatically illustrates the overall structure, four main components, two supplementary components, key concepts, and component relationships of the Interdisciplinary mHealth App Design Framework. Outlining the structure, components, concepts and relationships affords insight into the framework's justificatory and design knowledge, which informs its foundational principle form and function, and describes the abstract blueprint architecture of the framework (DSR artefact) (Gregor and Jones, 2007).

### 7.2.1 The Structure of the Interdisciplinary mHealth App Design Framework

The proposed Interdisciplinary mHealth App Design Framework, Figure 7.2, comprises four main components and two supplementary components to guide and support interdisciplinary

collaborating project teams through the process of designing, developing and evaluating mHealth physical activity behaviour change intervention apps. The framework's four main components include: (1) the *"actors"* – as the human, social relational and interactional theme (orange colour-coded); (2) the *"interdisciplinary collaborative process"* – as the pragmatic, processual and activity-orientated theme (blue colour-coded); (3) the *"boundary objects and supporting artefacts"* – as the artificial and sociomaterial theme (green colour-coded); and (4) *"knowledge"* – as the cognitive, conceptual and communication theme, which supports perspective sharing, sensemaking, learning and understanding between actors (pink colour-coded). The four components are strongly contingent on one another, complexly interwoven and intricately entangled in a pragmatic symbolic interactionist and sociomaterial reality. The framework's two supplementary components include the *"project boundary"*, which delineates the scope of a given mHealth intervention app project (yellow colour-coded), and the *"outcomes"*, which concerns the processual and product outcomes of given mHealth intervention app project (purple colour-coded).

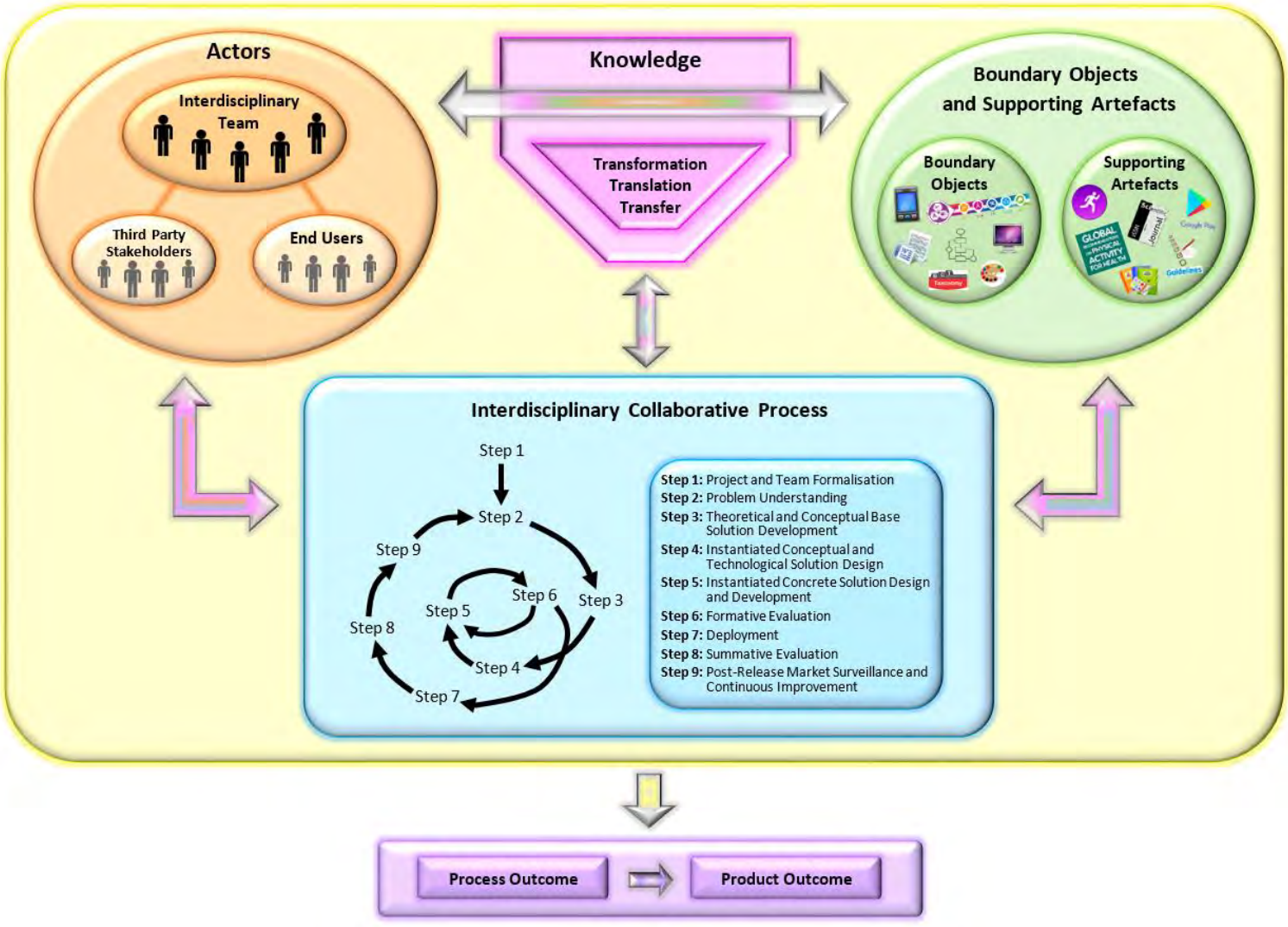





*Figure 7. 2: Proposed Interdisciplinary mHealth App Design Framwork [Source: Researcher's own construction]*

The framework highlights the main aspects necessary for consideration to guide and support interdisciplinary collaborating teams when carrying out projects intended for the design, development and evaluation of mHealth (physical activity) behaviour change intervention apps. The specific choice of component shapes (ovals, rectangles, and a half-octagon) and colours (orange, green, blue, purple, yellow and pink) applied in the framework (Figure 7.2) do not denote particular meaning other than clarifying distinctions between the several components. Exceptions to this is the use of darker and lighter shades of orange for the *"actor"* component, and the use of black versus dark grey actor symbols, which do convey meaning. The darker shade of orange with the black actor symbols depicts the *"interdisciplinary team"* at the forefront, leading the mHealth behaviour change intervention app project, while the lighter shade of orange with the dark grey actor symbols represent the *"third party stakeholders"* and *"end users"* (as target population representatives) as serving supplementary and auxiliary involvement in and contribution to a given mHealth intervention app project.

An additional colour-coded exception is the deliberate gradient colouring in the framework's five main grey arrows. The pink gradient shading in the four bidirectional grey arrows graphically depicts and represents how *"knowledge" flows* (is shared, transferred, translated and transformed) between the *"actors"* and *"boundary objects and supporting artefacts"* during the *"interdisciplinary collaborative process"*. The orange gradient shading in the three bidirectional grey arrows connotes *"actors"* as the social relational and interactionist carriers, users and enactors of *"knowledge"*, *"boundary objects and supporting artefacts"* and the *"interdisciplinary collaborative process"* steps and activities, respectively. The green gradient shading in the three bidirectional grey arrows conveys the sociomaterial, artificial and pragmatic entanglement of *"boundary objects and supporting artefacts"* as employed, utilised and created by *"actors"* during all nine steps of the *"interdisciplinary collaborative process"*, and as sociomaterial artefact holders, translators and mediators of *"knowledge"* between *"actors"* of heterogeneous practice communities. The blue gradient shading in the three bidirectional grey arrows conveys how the *"interdisciplinary collaborative process"* is complexly interwoven with *"actors"* who collaboratively enact the shared heteropraxial process steps and activities with *"boundary objects and supporting artefacts"*, and how the *"interdisciplinary collaborative process"* is both a carrier, translator, mediator and transformer for *"knowledge"* sharing between heterogeneous *"actor"* communities. The yellow gradient shading in the one unidirectional grey arrow graphically depicts how the crystallised

sociomaterial and pragmatic manifestations of the component entanglements occurring within the *"project boundary"* constitute and inform the process and product *"outcomes"*.

A high-level overview of the proposed framework graphically communicates that based on the sociomaterial interactions and practices performed by *"actors"* when sharing *"knowledge"* and using and creating *"boundary objects and supporting artefacts"* during the *"interdisciplinary collaborative process*" within the *"project boundary"*, *"outcomes"* are of intended result and effect. In other words, the performed/enacted process and resulting product output (mHealth intervention app) outcomes are a result of the interdisciplinary team's collaborative efforts within a defined project. Likewise with the five gradient colour-shaded grey arrows discussed above, the purple gradient shading in the one unidirectional grey arrow between the two nested *"outcomes"* is intentional, conveying how the first *"process outcome"* (on the left) informs and influences the second *"product outcome"* (on the right).

Notably, the contextual and situational elements of a given project, and surrounding a given project, further influence the outcomes of the interdisciplinary collaborating team's efforts and sociomaterial interactions. The multidimensional dynamic and entangled interrelationships and reciprocal determinism of the proposed framework's components is discussed in more detail throughout this chapter. The main component themes of the framework are initiated by the conception and inception of a new mHealth intervention app project by a diverse group (interdisciplinary collaborating team) of willing actors (community practice members) whom intend to design, develop, evaluate and produce an innovative mHealth (physical activity) behaviour change intervention consumer app.

#### 7.2.1.1 Main Component 1: Actors

The *"actors"* component, illustrated by the orange oval shape (with three nested ovals) (Figure 7.2), refers to the persons involved in any given mHealth (physical activity) behaviour change intervention app project. Actors can either *directly* participate as members of a project team (depicted as black actor symbols), or *indirectly* participate through third party stakeholder consultation or target population end user representative involvement (depicted as dark grey actor symbols). As for the direct type of involvement (the darker orange nested oval), actors consist of project and/or team leaders, primary empirical study facilitators and several team members. Together these actors constitute a project's *"interdisciplinary team"*, which can be described as the involvement of actors from different backgrounds who work together to span

competencies and bring together heterogeneous domain knowledge and practices, share the interdisciplinary collaborative process, and co-produce product output(s) (Lopez, et al., 2018).

Different aspects of a given mHealth intervention app project are intellectually stimulating to different members of the interdisciplinary team (Ben-Zeev, et al., 2015). Yet, although diverse and different, each team member contributes value to the shared design problem and solution (boundary) space (Bertelsen, 1998; Lopez, et al., 2018). According to the critical theoretical analysis findings (Chapter 6), the interdisciplinary collaborating team members can be democratically referred to as digital health intervention designers (or developers). The *project and/or team leaders* operate as strategically positioned knowledge brokers, meaning they guide, direct and manage both the interdisciplinary team and the mHealth intervention app project, and are "weakly linked to several communities at once … [yet are] full members of none" (Rosenkranz, Vranešić and Holten, 2014, p.310; Haas, 2015). The *primary empirical study facilitators* generally conduct, facilitate and supervise primary studies intended to gather information pertaining to the project, process and product, and work closely in assisting the project and/or team leaders (Olejniczak, 2017). Information gathered through empirical studies can relate to analyses, assessments, conceptual designs, prototypes, testing and evaluations. Examples include prototyping workshops (with experts and/or end users) or usability testing sessions (with a sample of end users) (Broberg, 2011). The remainder of the *general team members* operate as boundary spanners/boundary workers, stemming from a heterogeneity of practice communities (such as health sciences, health psychology, mobile design and development, user experience design, persuasive systems design, business management, data analytics, development and operations (DevOps), and more). As general team members, they serve as representatives of their localised communities of practice and disciplines, and contribute a diversity of knowledge, expertise and skills to the collaborative heteropraxial design, development and evaluation of mHealth (physical activity) behaviour change intervention apps.

As an interdisciplinary collaborating team, the actors – including those who act as knowledge brokers and those who stem from different communities of practice (as boundary spanners) – operate collectively as a community of interest (Lopez, et al., 2018). Functioning as a community of interest entails that they share the same mHealth intervention app project and share the same common interest and ultimate goal, which is to produce an innovative, well-designed and effective mHealth (physical activity) behaviour change intervention app. In order

to achieve an innovative hybrid solution, the interdisciplinary team engages in sociomaterial interactions and partake in communication, cooperation, coordination, collaboration and negotiation practices throughout the lifespan of a mHealth intervention app project.

In extending beyond the boundaries of the interdisciplinary team (Lopez, et al., 2018), the latter type of indirect involvement pertains to third party stakeholders' and target population end user representatives' involvements in a given mHealth (physical activity) behaviour change intervention app project. These actors' indirect participatory involvements is illustrated by the extended linking orange lines connecting to the two lighter orange nested ovals (Figure 7.2). These actors are not full members of the interdisciplinary team, but do engage in activities and contribute knowledge, skills, expertise and/or opinions at various stages of the project process, particularly when called upon by the team. An alternative way to phrase the distinction between direct and indirect involvement would be that the interdisciplinary team possesses the power and political positioning to drive the project, process and product output forwards (depicted by the darker orange actor group), whereas the third party stakeholders and end user participants are unable to exercise direct power or control over the project, process or product, but do indirectly influence the project outcomes (depicted by the lighter orange actor group). Overall, the *"actors"* constitute an essential component of successful mHealth (physical activity) behaviour change intervention app projects.

#### 7.2.1.2 Main Component 2: Interdisciplinary Collaborative Process

The "*interdisciplinary collaborative process*" (blue rectangle, Figure 7.2) refers to the design, development and evaluation steps (and comprising activities) necessary for a project team to perform to design, construct, refine, produce and deploy an effective mHealth (physical activity) behaviour change intervention consumer app (market product). The critical theoretical analysis findings (Chapter 6) identified nine key themes to inform the nine-step interdisciplinary collaborative process (Figure 7.2). Considering the dynamic, emerging and evolving interdisciplinary mHealth behaviour change intervention app landscape, several themes describe the characteristics and nature of the interdisciplinary collaborative process. Foremost, the proposed process assumes interdisciplinary and collaborative characteristics; of which the latter suggests that in order to traverse practice community boundaries and align common interests and project objectives, team members are required to consistently engage in communication, cooperation, coordination, negotiation and collaboration practices at each step of the shared interdisciplinary process. In addition, the nine-step process nature is portrayed by

an arrow-based iterative and flexible diagram, with numbered and labelled steps and unidirectional arrows (Figure 7.2). In terms of general structure, the process assumes a somewhat systematic and non-linear nature. The nine crescent-like arrows between steps 2 and 9 demonstrate the iterative cyclical (feedback looping), agile, continuous, flexible, adaptive, reflective and reflexive nature of the process. Alternatively, the straight arrow from step 1 to step 2 depicts a relatively more stable nature, considering that the activities of step 1 form (and inform) the grounding and foundational basis of the process (specifically the project's and team's formation and formalisation). Furthermore, the smaller cyclical (feedback) and reflective/reflexive circles of steps 4, 5 and 6 demonstrate faster prototyping iterations within the larger iterative and flexible process of a given mHealth intervention app project. In terms of quality, the process is theory-based and evidence-based, although this is not directly depicted in the diagram.

The "*interdisciplinary collaborative process*" comprises nine steps. The labels and brief descriptions of these nine process steps are outlined in Table 7.1 below.

*Table 7. 1: The Proposed Framework Interdisciplinary Collaborative Process: Step Numbers, Titles and Descriptions [Source: Researcher's own construction]*

| Process Step Number and Title | Description of Step(s) in the Multi-Disciplinary Process |
|---|---|
| ***Step 1:*** ***Project and Team Formalisation*** | The mHealth intervention app project and interdisciplinary team are established and formalised. Business, interdisciplinary process plan, common knowledge base and partnership agreements are formalised. |
| ***Step 2:*** ***Problem Understanding*** | The health problem, target health behaviour, target population group, digital platform and contextual factors are assessed, explicated and co-defined. |
| ***Step 3:*** ***Theoretical and Conceptual Base Solution Development*** | **Step 3.1 (Theoretical Base):** The health behaviour change intervention and digital technology (and user interaction) aims, objectives and scope are co-defined and specified.<br>**Step 3.2 (Conceptual Base):** The theory and evidence-based strategies, methods, standards and guidelines are specified as practical strategy applications. The shared visions of the theoretical base and conceptual base are co-developed. |
| ***Step 4:*** ***Instantiated Conceptual and Technological Solution Design*** | The theoretical and conceptual base solution is translated and operationalised into an instantiated co-conceptualised and co-developed digital platform mHealth intervention app design solution. |
| ***Step 5:*** ***Instantiated Concrete Solution Design and Development*** | Iterative prototyping and usability design-test-refine cycles are performed to produce a co-designed and co-developed (nearly fully functional) MVP alpha mHealth intervention app. |
| ***Step 6:*** ***Formative Evaluation*** | **Step 6.1 (Pilot Testing):** Pilot and feasibility tests are (iteratively) performed to co-produce a refined (fully functional) alpha mHealth intervention app.<br>**Step 6.2 (Beta Testing):** Beta tests are (iteratively) conducted to co-produce a refined mHealth intervention app as a beta release candidate. |

| | |
|---|---|
| ***Step 7:*** ***Deployment*** | A deployment plan and business plan are co-produced for the mHealth intervention app's public commercial release. The beta release candidate is deployed to consumer app market stores. |
| ***Step 8:*** ***Summative Evaluation*** | Summative evaluations are conducted on the beta release candidate to measure its quality, engagement, efficacy and effectiveness over time. A refined mHealth intervention app is co-produced and released on commercial consumer app market stores. |
| ***Step 9:*** ***Post-Release Market Surveillance and Continuous Improvement*** | Subsequent to the mHealth intervention consumer app's public release on the commercial app market, continuous tracking, monitoring, maintenance, testing and improvement updates are executed over the remaining lifespan of the app. Business and monetisation analyses are performed, and project reports are published and disseminated. |

Important to note is that the nine steps proposed in the interdisciplinary collaborative process offers comprehensive and general, rather than rigid and specific, guidance for teams to use during an mHealth intervention app project's lifespan. In other words, the process steps are flexible and adaptable to different projects, teams and contexts, and do not inforce a strict prescriptive approach. Some steps may be performed simultaneously, while others may be carried out iteratively a number of times. Considering the comprehensiveness of the proposed process, some steps may be disregarded all together. For example, a team may make a collaborative consensus decision to not perform Step 6.1 (formative evaluation pilot testing sessions), and rather transition from Step 5 (developing an instantiated concrete solution design) to Step 6.2 (formative evaluation beta testing sessions) in order to save time, costs and resources. Furthermore, the process is contextually flexible in that a team may arrange for some arrows to flow between steps not illustrated in Figure 7.2. For instance, an arrow (or arrows) may flow from Steps 5 and/or 6 into Steps 3 and/or 4, demonstrating refinement from prototyping stages back to theoretical and instantiated solution designs, respectively.

The core purpose of the proposed framework's comprehensive and general prescribed interdisciplinary collaborative process is simply to highlight steps and activities identified in literature as necessary and/or valuable for producing a good quality theory and evidence-based effective mHealth app product for consumer app. The particularised and definitive pragmatic application of an interdisciplinary collaborative process (and its steps and activities) are at the discretion of the interdisciplinary team in relation to a specific project's context, objectives and ultimate goal.

There are two justifications for proposing a flexible comprehensive and general interdisciplinary collaborative process. Firstly, the emerging interdisciplinary mHealth behaviour change intervention app arena is ever changing and continues to evolve over time,

which means that prescribing a rigid and inflexible process would be restrictive of adaptation, creativity and innovation in the face of ongoing advancements. Secondly, mHealth (physical activity) behaviour change intervention app projects, by intrinsic nature, embody ill-defined, messy and wicked design problems (Simon, 1996; Fischer, et al., 2005), for which there are no absolute, correct or perfect design solutions (Henderson, 1991; Lopez, et al., 2018; Sander, Nolwenn and Céline, 2019). Design work is therefore described as an inherently heteropraxial endeavour (Bertelsen, 1998; 2000) and collective activity and process that necessitates design knowledge sharing and collaborative, sociomaterial practices and processes stemming from multiple disciplines and perspectives (Lopez, et al., 2018). Prescribing a rigid and inflexible process would be infeasible given the complex and wicked nature of mHealth intervention app design problems and solutions, and would hinder the innovative collaborative heteropraxial design process for interdisciplinary project teams.

Boundary objects, and design boundary objects in particular, therefore become of "crucial importance" and "significance" between actors of the collaborative interdisciplinary mHealth behaviour change intervention app process; serving as valuable anchor points for meaningfully synthesising diverse perspectives into novel and innovative mHealth consumer app product solutions (Sander, Nolwenn and Céline, 2019, p.13). As demonstrated through this explanation, the intricately interwoven entanglement between the *"actors"*, *"(design) boundary objects and supporting artefacts"*, *"interdisciplinary collaborative process"* and *"knowledge"* becomes apparent and evident. These multifaceted and multidimensional entanglements are illustrated in Figure 7.2 by the two gradient colour-shaded grey bidirectional (90 degree) right-angle arrows and the short pink and blue gradient shaded grey bidirectional straight arrow; all three of which surround and link with the *"process"* component. These three arrows portray a simplified and abstract representation of the components' complicated entanglements. Overall, the *"interdisciplinary collaborative process"* represents an indispensable component of successful mHealth (physical activity) behaviour change intervention app projects.

#### 7.2.1.3 Main Component 3: Boundary Objects and Supporting Artefacts

The green oval shaped component in Figure 7.2 pertains to the various artificial and sociomaterial *"boundary objects and supporting artefacts"* that are employed, utilised and (iteratively) created (and refined) by the interdisciplinary team (*"actors"*) during the *"interdisciplinary collaborative process"* of any given mHealth (physical activity) behaviour change intervention app project. When engaging in collaborative processes and practices,

various artefacts, (design) boundary objects and supporting methods and materials become an inevitable part of the mHealth project process and setting (Ben-Zeev, et al., 2015; Filip, 2016).

"*Boundary objects*" in particular, illustrated as the smaller left-hand green circle (Figure 7.2), function as valuable artefacts in fostering, supporting, facilitating and mediating collaborative, cooperative and coordinated interdisciplinary project teamwork (Star and Griesemer, 1989; Melville-Richards, 2015). More specifically, the characteristics and properties of boundary objects (and design boundary objects) support interdisciplinary team boundary crossing and boundary spanning activities, and help facilitate the transfer, translation and transformation of *"knowledge"* between interacting heterogeneous team members (*"actors"*). Examples of boundary objects include shared processes, shared methods, taxonomies, common glossaries, shared documentation, shared maps, and CAD and app prototyping software (illustrated as small icons in the *"boundary objects"* green circle, Figure 7.2). For collaborating interdisciplinary team members, boundary objects also act as reminders for triggering relevant (implicit and explicit) design knowledge, afford flexible representations of (creative) ideas, are useful for articulating and externalising different (actor) perspectives, and function as conversation pieces for aiding the attainment and grounding of shared (knowledge) understanding and objectives (Fischer, et al., 2005; Lopez, et al., 2018).

Design boundary objects (a particular type of boundary object) refer to the objects and artefacts that function as a means of representing, mobilising, bridging, learning about, legitimising and transforming design knowledge at the boundaries between team members stemming from different practice communities (Bertelsen, 1998; Henderson, 1998; Bergman, Lyytinen and Mark, 2007; Johnson, et al., 2017). Design boundary objects support team members in mediating design activities, practices, processes and knowledge, and tie team members together by providing a joint focus on the same design object (for example, a sketch or model) or the same object of design (that is, the mHealth intervention app) (Bertelsen, 1998). Examples of commonly utilised design boundary objects by teams in mHealth intervention app projects include (low- to high-fidelity) sketches, storyboards, diagrams, models, maps and app prototypes (illustrated by the sketch and mobile icons in the *"boundary objects"* green circle, Figure 7.2). Infrastructural and material boundary objects further support the actors' design processes and activities; for example, creative craft materials (depicted by the art palette icon, Figure 7.2) that can be employed during idea generation and design solution workshops during steps 3.2 and 4 of the *"interdisciplinary collaborative process"* (Approaches #14; #15; #16).

*"Supporting artefacts*", illustrated as the smaller right-hand green circle (Figure 7.2), refer to objects, materials, methods and artificial 'things' that support and assist interdisciplinary team collaborative activities, tasks and knowledge sharing practices during the project process. Notably, these supporting artefacts do not meet the three core criteria of boundary objects, but are useful and helpful for designing, developing and evaluating mHealth (physical activity) behaviour change intervention apps. An example of a supporting artefact (illustrated as a dark green square artefact icon in the *"supporting artefacts"* green circle, Figure 7.2) is the WHO's evidence-based global recommendations for physical activity (WHO, 2010b; 2020c). The WHO's global physical activity guidelines can be a supporting artefact the interdisciplinary team members refer to when designing the theoretical base solution of a mHealth physical activity behaviour change intervention app during step 3.1 of the *"interdisciplinary collaborative process"*. Additional evidence-based physical activity and exercise guideline and recommendation artefacts (such as national, provincial, institutional or exercise- or training-specific programme guidelines) are depicted by the small purple running icon in the *"supporting artefacts"* green circle (Figure 7.2). Another example of supporting materials are mobile app operating system policies, such as Android's app developer policies (depicted by the google play store icon, Figure 7.2) covering privacy, security, intellectual property, monetisation and advertisements, store listing, spam, and policy enforcement and violation. Based on the critical theoretical analysis findings (Chapter 6), published literature and empirical studies (portrayed as a scientific journal icon, Figure 7.2) are used as supporting artefacts the interdisciplinary team members can refer to at any step or activity of the *"interdisciplinary collaborative process"*.

Overall, there exist a multitudinous array of boundary objects and supporting artefacts that interdisciplinary collaborating team members can employ, utilise and create (and refine) at various stages (and points in time) of the mHealth behaviour change intervention design, development and evaluation process. The critical theoretical analysis findings (Chapter 6) reveal that it is foolish and infeasible to state all possible boundary objects and supporting artefacts. However, a collection of commonly utilised and created artefact themes can be identified across literature (Chapters 5 and 6). The themes and subthemes (as categories and types) of both the boundary objects and supporting artefacts are discussed in more detail in Section 7.5. On the whole, *"boundary objects and supporting artefacts"* signify a fundamental and invaluable component of successful mHealth (physical activity) behaviour change intervention app projects, and are complexly entangled with *"actors"*, *"knowledge"* sharing

and *"interdisciplinary collaborative process"* step and activity practices – depicted in Figure 7.2 by the one long gradient coloured grey bidirectional arrow and the two gradient coloured grey bidirectional (90 degree right-angle) arrows.

#### 7.2.1.4 Main Component 4: Knowledge

The "*knowledge"* component represents the continuous transfer, translation and transformation of knowledge throughout the lifespan of any given mHealth (physical activity) behaviour change intervention app project. In Figure 7.2, *"knowledge"* is portrayed as a pink half-octagon positioned between and associated with the three other main components. These core component relationships, illustrated by the pink gradient colour shading included in the four grey bidirectional arrows, depicts how *"knowledge"* is fundamentally entangled with *"actors"*, *"boundary objects and supporting artefacts"* and the *"interdisciplinary collaborative process"* of any given mHealth intervention app project. In terms of actors, knowledge (in implicit, tacit and explicit form) exists in the minds of the heterogeneous collaborating team members, informed by their respective disciplinary fields of specialisation, practical experience and diverse community of practice backgrounds. The employment and use of sociomaterial artefacts and (design) boundary objects can enable, facilitate and mediate the relational and interactional sharing of knowledge across team members' diverse practice community boundaries (Carlile, 2002; 2004). With regard to the process component, knowledge is referenced cognitively and externally to guide, inform and support actors' enactments of process steps, activities, tasks and collaborative practices. At the same time, knowledge is also explicated communicated, reconstructed and newly generated through actors' engagements with and reflective/reflexive enactments of process steps, activities and collaborative practices.

In new product development (such as mHealth behaviour change intervention consumer apps), knowledge boundaries arise due to differences in language, interpretation of meaning, work (activity) practices and interests between diverse communities of practice (Carlile, 2002). Collaborative and joint (design) problem solving and mHealth intervention app product development therefore requires heterogeneous team members to overcome syntactic, semantic and pragmatic knowledge boundaries by developing common vocabulary and language(s), common meanings and common interests, respectively (Carlile, 2002; 2004). These three knowledge boundaries and solutions correspond to the three knowledge boundary processes – namely the *"transfer"*, *"translation"* and *"transformation"* of *"knowledge"* – specified in the pink inverted triangle (nested in the pink half-octagon) in Figure 7.2.

The pink inverted triangle (Figure 7.2) signifies an (ascending) increasing scale of complexity, in which differences, dependencies and novelties increase as heterogeneous collaborating actors aim to exchange (transfer), deliberate (translate) and negotiate (transform) knowledge (and power stakes) at a given knowledge boundary (Carlile, 2002; 2004). Furthermore, the development of shared mental models and shared understanding becomes imperative to the productivity and success of collaborative interdisciplinary (design) processes and projects (Koskela, et al., 2016). Shared understandings and shared app (design) vision solutions represent intangible internalised cognitive artefacts (Engeström, Engeström and Kärkkäinen, 1995; Cash, Dekoninck and Ahmed-Kristensen, 2017) that are necessary for integrating knowledge (Koskela, et al., 2016), reasoning around conflicting perspectives, and coordinating team members' actions towards achieving common project and app product goals and objectives (Gomes and Tzortzopoulos, 2018). Ultimately, the collaborative sharing, integration, transformation and co-creation of knowledge materialises to form a hybrid (interdisciplinary) mHealth (physical activity) behaviour change intervention app design solution. Knowledge ultimately becomes crystallised in the final mHealth behaviour change intervention consumer app product output. Overall, *"knowledge"* is an essential component of successful mHealth (physical activity) behaviour change intervention app projects.

#### 7.2.1.5 Supplementary Component 1: Project Boundary

The large yellow rectangle in Figure 7.2 denotes the "*project boundary"* of any given mHealth (physical activity) behaviour change intervention app project. Within the boundaries of a given project and context, a particular interdisciplinary team is established (and contracts are formalised), a specific co-defined interdisciplinary collaborative process (comprising several steps) is carried out, a variety of (design) boundary objects and supporting artefacts are employed, utilised and created, and a variation of knowledge is shared and co-created. Notably, the solid yellow line (Figure 7.2) depicting the boundary of any given mHealth intervention app project is not definitive, fixed, rigidly defined or impermeable. The boundaries and interfaces between interdisciplinary team members (stemming from heterogeneous intersecting communities of practice) are, by nature, blurry and fuzzy, flexible, porous and permeable (Brown, Crawford and Darongkamas, 2000). Furthermore, the solid yellow boundary line drawn around the four main components (Figure 7.2) does not suggest that the project (or its components) exist in isolation or are unaffected and uninfluenced by surrounding contextual, situational, cultural, historical and socio-environmental factors. The delineation does, however, intend to illustrate and convey that a project boundary should provide an interdisciplinary

collaborating team with sufficient structure and scope, in which the team members (actors) are able to flexibly engage in knowledge, processual and activity-orientated communication, coordination, cooperation, collaboration, and integration practices.

It is within any given mHealth intervention app project's boundaries that the interdisciplinary collaborating team members are able to participate in mutual learning, shared understanding and interactive and sociomaterial collective engagements (such as co-defining, co-designing, co-developing and co-producing activities) with the intention of collaboratively and cooperatively creating (co-creating) creative and innovative design ideas and mHealth intervention consumer app product solutions (Sander, Nolwenn and Céline, 2019). Moreover, it is within the boundaries of a project that the interdisciplinary collaborating team shares an mHealth behaviour change intervention app design problem and solution (boundary) space, and develops team culture, dynamics and practices applicable to the particular project and context at hand (Bertelsen, 1998). Lastly, considering that the mHealth behaviour change intervention app landscape (which incorporates several diverse practice communities) is constantly evolving and advancing, the boundaries of any given mHealth intervention app project (and its comprising components) are adaptable, pliable and transformable over time as a project evolves and changes shape throughout its project lifespan.

#### 7.2.1.6 Supplementary Component 2: Outcomes

The second supplementary "*outcomes*" component is illustrated as a purple rectangle, positioned outside of the *"project boundary"* (Figure 7.2). The *"outcomes"* are portrayed as a resulting effect (unidirectional purple gradient colour shaded grey arrow) of the systemised social and material (sociomaterial) praxes and the entangled enactment of the main components within a given project. The two outcome themes are categorised as a *"process outcome"* and a *"product outcome"*, corresponding to primary and secondary outcomes, respectively. The *"process outcome"* refers to the output result from an enacted boundary object-supported and knowledge-integrated collaborative process performed by interdisciplinary team members within a given project boundary and context. The process steps and activities guide and support interdisciplinary team members' communicative, coordinated, cooperative and collaborative efforts. These collaborative efforts involve the employment, use and creation of (design) boundary objects and supporting artefacts to facilitate and mediate knowledge sharing and knowledge building across diverse practice community boundaries during the interdisciplinary collaborative process.

The interdisciplinary team's efforts and contributions during the process are ultimately focused on designing, developing and evaluating an effective mHealth (physical activity) behaviour change intervention app (as the team's shared vision and common goal). The *"product outcome"* therefore refers to the mHealth (physical activity) behaviour change intervention consumer app that is produced by the interdisciplinary team as an output result of the enacted interdisciplinary collaborative process. The *"product outcome"* is also a resulting output of the mHealth intervention app project as a whole. In more granular terms, the mHealth intervention app "product" is a(n) (iteratively refined) material manifestation of interdisciplinary collaborative crystallised design knowledge sharing and knowledge integration, and heteropraxial design, development and evaluation activity practices. To phrase the relationship between the two outcomes more simply, the interdisciplinary collaborative process directly and indirectly effects the mHealth intervention app product output. This relationship link between the two outcomes is illustrated by the unidirectional purple-grey gradient coloured arrow in the purple rectangle *"outcomes"* component (Figure 7.2).

## 7.3 Actors

### 7.3.1 Actors: A Detailed Perspective

Figure 7.3 provides a clipping of the "*actors*" component from Figure 7.2, which as discussed in Subsection 7.2.1.1, pertains to the human and social relational aspect of the proposed framework and comprises persons who are categorised as either direct project "*interdisciplinary team members*" or indirect "*third party stakeholders*" or "*end users*". In honing in on the *"actors"* component of Figure 7.3, Figure 7.4 presents a more detailed perspective of the "*actors*" and communities of practice that are directly and indirectly involved in mHealth behaviour change intervention app projects.

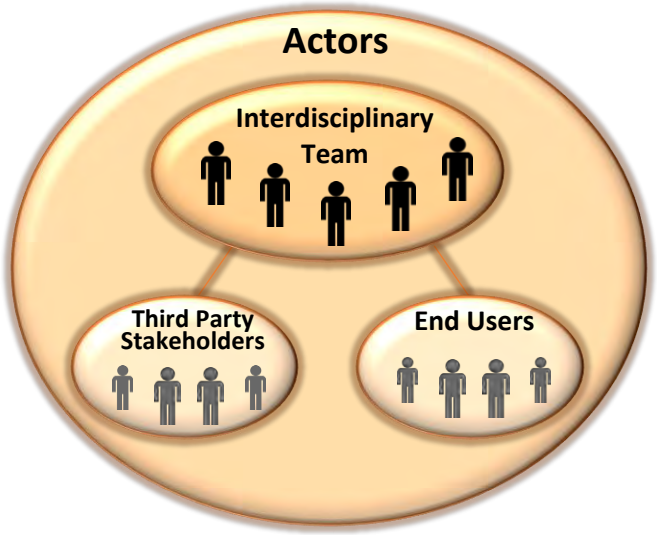



*Figure 7. 3: "Actors": Main Component 1 of the Proposed Framework*
*[Source: Researcher's own construction]*

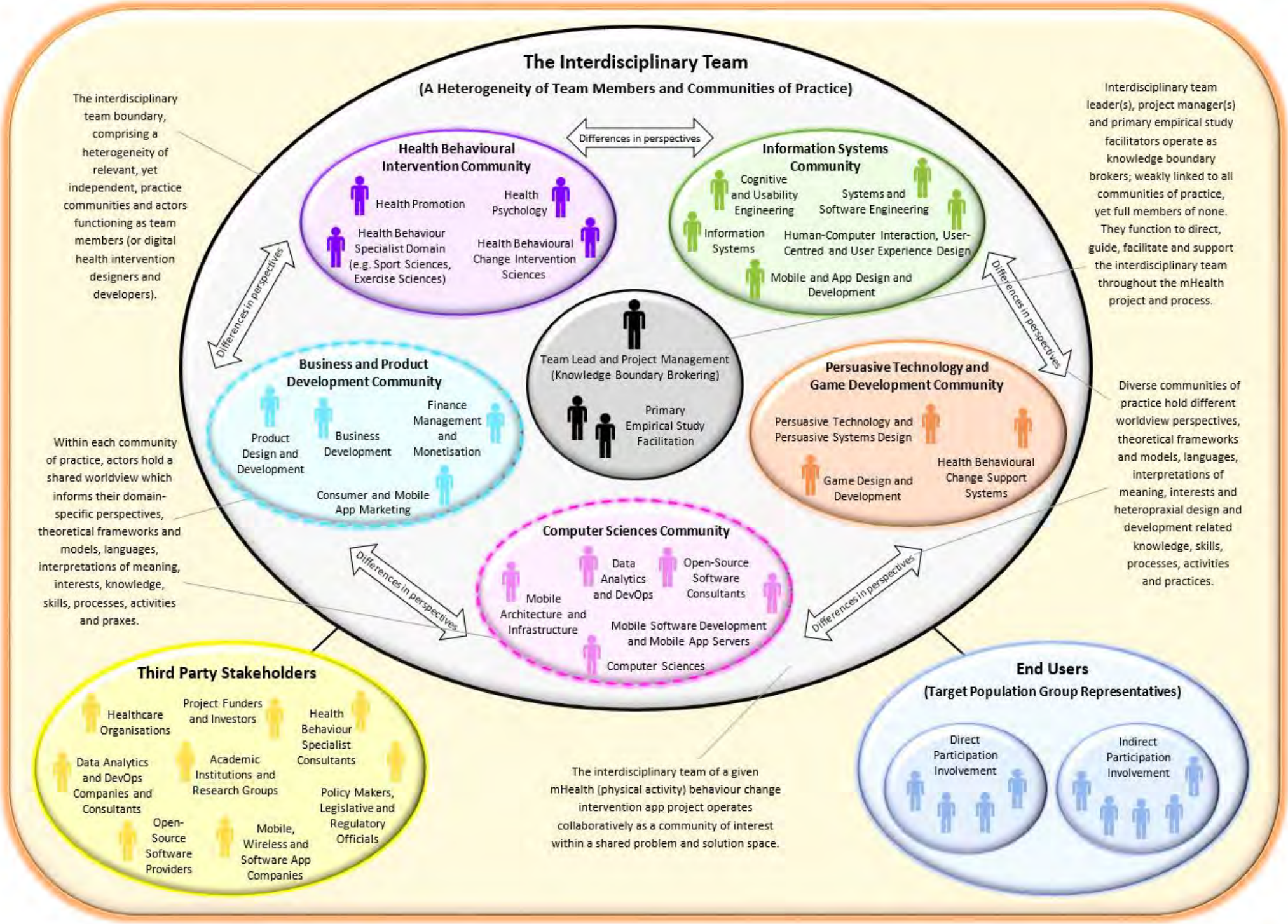



*Figure 7. 4: "Actors" Detailed Perspective: Main Component 1 of the Proposed Framework [Source: Researcher's own construction]*

#### 7.3.1.1 Actors: The Interdisciplinary Team

In Figure 7.4, *"the interdisciplinary team*", constituting knowledge brokers and a heterogeneity of general team members from diverse communities of practice, is positioned within "*the interdisciplinary team boundary*", depicted by the large black oval shape. Similar to Figure 7.2, the eleven oval shapes (in total) and colours in Figure 7.4 do not signify specific meaning, other than distinguish boundary and community representations. As an interdisciplinary collaborating team (within the thick black-lined boundary), the team members function as a community of interest (Lopez, et al., 2018) in the shared design problem and solution boundary space, and share the same project and the same ultimate goal, which is to work together to produce an innovative mHealth (physical activity) behaviour change intervention consumer app.

Overall, the *interdisciplinary collaborating team members* function as direct participants, meaning they are directly involved in the project, and possess (various levels of) power, influence and political positioning to drive forward and control (or delay/halt) the progress of the project, process and product (app). The *team leader and/or project manager* and the *primary empirical study facilitator(s)* are portrayed as black actor symbols (Figure 7.4), demonstrating their significance, nested centrally within the interdisciplinary team. The black solid (and relatively thicker) line around them and the shaded grey background (Figure 7.4) illustrates their overarching positioning and political and decision-making power over-and-above the rest of the general team members. Their positioning, power and influence offers both advantages and disadvantages, evident through their roles and responsibilities as knowledge (boundary) brokers (discussed further in the knowledge component, Section 7.6). Notably though, while the team leader, project manager and primary empirical study facilitators function similarly in their roles as knowledge brokers, the team leader and/or project manager hold primary chief reign and power over the team, project, process and product, while the primary empirical study facilitators exercise secondary reign and facilitation power when conducting and coordinating primary empirical studies at particular stages of the mHealth project and process. These distinctions in primary and secondary reign and positioning is denoted through the slightly larger team leader and project manager black actor symbol, and the relatively smaller primary empirical study facilitator(s) (Figure 7.4). Aside from reign and positioning, as knowledge brokers, these actors are required to remain impartial to any specific community of practice, and are best described as "weakly linked to several communities at once… [yet are] full members of none" (Rosenkranz, Vranešić and Holten, 2014, p.310).

Numerically, this proposed framework does not strictly suggest as to how many team leaders, project managers and primary empirical study facilitators should be recruited for mHealth intervention app projects. Accordingly, the three actor symbols illustrated centred in the grey-shaded oval in Figure 7.4 is not strictly prescriptive. Furthermore, there is no rigid policy advising whether the team leader and project manager should be the same person, or two (or more) persons. The number of team leaders, project managers and primary empirical study facilitators elected to guide, direct and manage the team and mHealth intervention app project is at the discretion of the team, and should be determined with consideration for the project, problem and (intended) solution context. For instance, the larger the project scope, the more likely a bigger interdisciplinary team will be required, and more leaders, managers and facilitators will be recruited and elected, and vice versa for smaller projects.

The rest of the general interdisciplinary team members (outside of the black-lined and grey shaded oval, Figure 7.4) are portrayed as localised within their own communities of practice, surrounding the central project knowledge brokers. Likewise with the relative actor symbol size distinction between team leaders/project managers and primary empirical study facilitators, the actor symbols for the rest of the general interdisciplinary team members are comparably smaller, conveying less reign positioning, political influence and decision-making power within the overall interdisciplinary team. The graphical encircling of the heterogeneous team members around the knowledge brokers depicts their positioning and responsibility towards the knowledge brokers, and that their boundary spanning, boundary crossing and knowledge sharing practices are managed, facilitated and coordinated by and through the central knowledge brokers.

Boundary spanning (Levina and Vaast, 2005; Rosenkranz, Vranešić and Holten, 2014) and boundary crossing (Akkerman and Bakker, 2011) refers to the actors' efforts at the respective community boundaries to establish, negotiate and restore continuity in practice or sociomaterial action and interaction across the collaborating heterogeneous practice communities (Bakker and Akkerman, 2014). Boundary spanning and crossing transpires as general team members (localised within their own communities) enter into unfamiliar territory (that is, the intersecting shared problem and solution space) in which they lack specialised knowledge, qualifications, skills, expertise and experience (Suchman, 1994). Related to these practices is knowledge sharing, essentially the process through which different knowledge is exchanged between the interdisciplinary collaborating team members at their respective community boundaries

(Rosenkranz, Vranešić and Holten, 2014). Metaphorically, the knowledge brokers are the glue that holds the heterogeneous interdisciplinary collaborating team members together, and are the actors that guide, direct and support the rest of the team in carrying out boundary spanning, boundary crossing and knowledge sharing processes, practices and activities throughout the duration of the mHealth intervention app project.

As pictured in Figure 7.4, the heterogeneous interdisciplinary team members stem from five different practice communities (knowledge domains and fields of expertise), denoted by the alternate community boundary and actor symbol colours; specifically purple, green, light blue, pink and orange. These colours correspond to the *"health behavioural intervention community"*, the *"information systems community"*, the *"business and product development community"*, the *"computer sciences community"*, and the *"persuasive technology and game development community"*, respectively. Important to note is that these communities represent overarching communities, encompassing clustered practice communities within them. For example, the *"health behavioural intervention community"* comprises several actors from the disciplines and fields of "health promotion", "health psychology", "health behavioural change intervention sciences" and project and product relevant "health behaviour specialist domains" (such as physical activity experts, sport sciences and exercise sciences). Likewise with the knowledge brokers, the number of general interdisciplinary team members stemming from each of the five clustered practice communities is not strictly prescriptive, and may range depending on the scope, nature and context of the team composition and project. For example, a given mHealth intervention project may have two physical activity knowledge experts in their interdisciplinary team. For purposes of pictorial simplicity, only one colour-coded actor symbol is associated with each clustered community in Figure 7.4, and colour-coded actor symbols correspond to the colour of their broader practice community.

The titles of the five overarching communities (and their clustered nested communities) are informed by the critical theoretical analysis findings (Chapter 6, Subsection 6.5.2), and are clustered based on general (abstracted) shared worldview perspectives, theoretical frameworks and models, languages, interpretations of meaning, interests, knowledge, skills, processes, activities and praxes. The five bidirectional arrows drawn between the five overarching communities of practice (Figure 7.4) connote the abstracted *"differences in perspectives"* held by each of the collaborating team members and practice communities. Knowledge brokers serve as intermediaries to mediate these differences in perspectives (Haas, 2015), as translators

in establishing and maintaining links between the heterogeneous communities (Meyer, 2010), and as facilitators and negotiators that bring diverse actors and practice communities together so that they can share and create ideas, knowledge and practices (Blackman, Kennedy and Ritchie, 2011).

To further elaborate on the general interdisciplinary team members/practice communities in Figure 7.4, it is necessary to highlight that while the random selection of five (purple, green, light blue, pink and orange) practice community colours do not convey meaning, significance is however conveyed through the distinguishing use of the three solid (purple, green and orange) colour community of practice lines and the two dashed (light blue and pink) colour community of practice lines. This clarification is important to justify since it concerns the depth of investigation and knowledge contribution for each of the five overarching communities in this research project. Firstly, this research project is primarily situated in and contributes to the "information systems" field and knowledge base, of which the "persuasive technology and game design and development" domains are subfields (and overlap with other domains). Secondly, the "health behavioural intervention" field is of imperative investigation and understanding considering its embeddedness in the topic and area of study in this research project. The latter pertains to the health (promotion) behavioural change intervention context, and the former concerns the digital and technological platform (mode) through which these health behaviour interventions are delivered to individuals as consumers (at the dual intra-interpersonal socioecological levels). Thirdly, in comparison to the three (sold line) communities, the two (dashed line) "business and product development" and "computer science" communities are of relevance to, but are not the primary focus of, this research project. The "business and product development" and "computer sciences" team members/practice communities contribute directly to mHealth (physical activity) behaviour change intervention projects, and therefore are recognised and included in Figure 7.4. However, this research project does not seek to directly contribute to the business and management knowledge base (for example, in terms of business administration, strategic planning and monetisation models) nor does it seek to directly contribute to the technical computer science knowledge base (for example, in terms of databases, hardware, programming, networking, privacy and security). Essentially, the important contributory role of the "business and product development" and "computer sciences" communities are acknowledged and included in this proposed framework, but further in-depth investigation into and knowledge contributions to these communities is scoped out for future research.

#### 7.3.1.2 Actors: Third Party Stakeholders and End Users

In extending beyond the interdisciplinary team boundary (the large black line oval shape, Figure 7.4), the "*third party stakeholder*s" and "*end users*" represent two groups of participants who are indirectly involved in any given mHealth (physical activity) behaviour change intervention app project. An exception to this indirect involvement is the *"direct participation involvement"* subgroup of *"end users"* (bottom blue shaded left circle in Figure 7.4), discussed under *"end users"* below. Nevertheless, the extensions are illustrated by the two black lines connecting the interdisciplinary team, and third party stakeholders and end users respectively. This extension conveys that these actors are not full members of the interdisciplinary team, but do engage in activities and contribute a diversity of knowledge, skills, expertise and/or opinions and feedback at various stages of the project process, particularly when called upon, contracted or partnered with by the interdisciplinary team.

***Third Party Stakeholders***

In terms of the bottom left yellow oval-shaped "*third party stakeholders"* cluster (Figure 7.4), these actors or communities include "project funders and investors", "health behaviour specialist consultants", "healthcare organisations", "academic institutions and research groups", "data analytics and DevOps companies and consultants", "open-source software consultants", "mobile, wireless and software app companies" and "policy makers and legislative and regulatory officials" (Figure 7.4). DevOps refers to a set of combined practices that automates the processes between software development (Dev) and information technology operations (Ops), and aims to shorten the systems or mobile app development lifecycle and provide continuous delivery and continuous testing while maintaining high quality standards (Francis, 2017; Taylor, 2018; Mala, 2019).

An example can help clarify third party stakeholder indirect involvement. An interdisciplinary team may, for instance, contract a physical activity and exercise specialist (who would be classified as a type of "health behaviour specialist consultant") during Step 3 ("theoretical and conceptual base solution development") or Step 5 ("instantiated concrete solution design and development") of the interdisciplinary collaborative process. The intention for their involvement in this instance would be to provide expert knowledge, insight and opinions/feedback/suggestions relevant to a particular mHealth physical activity behaviour change intervention consumer app product. Their involvement is indirect in that they do not possess the team-related positioning and political power to make final decisions (that is,

whether the expert input/feedback will be accepted or rejected), although their knowledge and contributions is capable of influencing and persuading the interdisciplinary team's product decisions. An exercise specialist may, for instance, suggest incorporating the WHO's global physical activity guideline recommendations (WHO, 2010b; 2020c) into the theoretical, conceptual or concrete design solution, which would influence the output product produced by the team. However, when not called upon, contracted or consulted by the team, the third party stakeholders are not required to be present, are not full direct members of the interdisciplinary team, and remain localised in their own external communities outside the interdisciplinary team boundary (Ferguson, 2018). Another example would be contracting an app developer as an "open-source software consultant", who possesses knowledge, skills and expertise with open-source app development software (such as Fuse Open, Flutter, BuildFire and Ionic). An open-source software app developer would be capable of contributing during Step 5 of the process, when iteratively developing a concrete instantiation of a given mHealth physical activity behaviour change intervention consumer app.

Likewise, with the five overarching practice communities, the third party stakeholders are identified based on the critical theoretical analysis findings (Chapter 6, Subsection 6.5.2). Notably though, the third party stakeholders identified in the proposed framework are not exhaustive, and not every identified stakeholder is necessarily required to participate in or contribute to all mHealth intervention app projects. The partnering, contracting, consulting and involvement of indirect third party stakeholders (and how many) is at the discretion of the interdisciplinary team, and varies in relation to the project team, scope, context and objectives.

***End Users***

The bottom right powder blue oval-shaped "*end users*" cluster (Figure 7.4) forms the second extension from the interdisciplinary team. Based on the critical theoretical analysis findings (Chapter 6, Subsection 6.5.2), end users, who serve as representatives of their respective target population groups, can participate either directly or indirectly in mHealth intervention app projects, processes and activities. On the one hand, *"direct participation involvement"* describes end users who serve as general members of the interdisciplinary collaborating team (within the black-lined team boundary), and who are generally involved through participatory and co-design processes. The multi- and interdisciplinary digital health intervention development approaches discussed in Chapter 6 (Section 6.4.3), namely Approaches #13 to #16, provide examples of direct end user participatory involvement, in which case end users

are able to exercise influence and decision-making power over the project, process, activities, product and outcome(s). On the other hand, *"indirect participation involvement"* describes end users who serve as target population group representatives partaking in certain steps and activities of the interdisciplinary collaborative process, most noticeably in (and closely) during the iterative prototyping stages of Steps 4, 5 and 6, and later during Steps 8 and 9 (albeit more distantly). The critical theoretical analysis findings revealed that indirect participation involvement is far more common practice than direct participation involvement. This is particularly due to the additional time, costs and resources necessary to run participatory and co-design processes, deeming indirect participatory involvement a more cost-effective option.

The decision(s) made as to whether end users should be involved as direct or indirect participants, and at which steps/activities of the process they participate, is not strictly prescribed by this proposed framework, but rather is at the discretion of the interdisciplinary team. Regardless, the decision made should align with the underpinning philosophy and nature of the defined interdisciplinary collaborative process and should be congruous with the project context and product objectives.

In referring back to Figure 7.4, for purposes of reducing diagrammatic complexity, the *"direct"* end user subgroup is drawn outside of the interdisciplinary team boundary (that is, outside of the thick black-lined team boundary). However, in the event that the interdisciplinary team chooses to recruit and involve end users to participate directly in the project as general team members, then the small powder blue *"direct participant involvement"* subgroup oval would be repositioned within the thick black-lined interdisciplinary team boundary, along with the other five identified communities. This alternate approach is deliberately not graphically illustrated in Figure 7.4 since the *"indirect"* end user subgroup involvement was comparably a more apparent theme of the literature and critical theoretical analysis findings, and more so that it may unnecessarily complicate the diagram. Moreover, for further reasons of graphical simplicity, only four and five powder blue actor symbols have been included in the two *"direct"* and *"indirect"* community subgroups in Figure 7.4, respectively. Likewise with the number of actor symbols in the interdisciplinary team and third party stakeholder elements, the number of end users chosen to participate in and contribute to various process steps and activities is at the discretion of the team (or the team leader/project manager/primary empirical study facilitators) and again depends on the project context and the product and step/activity objectives.

#### 7.3.1.3 Actors: A Summary Overview of the Actors

Table 7.2 provides a brief summary overview of the actors discussed in Section 7.3, by outlining the heterogeneous communities of practice (and hence the different interdisciplinary team members) with direct participatory involvement in any given mHealth (physical activity) behaviour change intervention app project, as well as the third party stakeholders and end users with indirect participatory involvement. In Table 7.2, for each identified practice community, a brief description and a few actor examples are provided. A more detailed summary overview of the actors discussed in Section 7.3, with elaborated descriptions, identified sub-communities, more examples and reference sources (from both literature and the critical analysis findings) is provided in Appendix J.1.

*Table 7. 2: Actors Summary Overview [Source: Researcher's own construction]*

| Overarching Community of Practice | Overarching Community of Practice and Actor Description | Examples of Actors |
|---|---|---|
| **Interdisciplinary Team** | The interdisciplinary team of heterogeneous actors are localised in a diversity of practice communities, and engage in boundary spanning/crossing and knowledge sharing practices within a shared project boundary problem and solution space. | • Interdisciplinary Team Leader<br>• Project Manager<br>• Community of Practice (localised) General Team Members<br>• Digital Health Intervention Team Designer<br>• Digital Health Intervention Team Developer |
| **Team Lead and Project Management**<br><br>**Primary Empirical Study Facilitation** | The team leader(s), project manager(s) and primary empirical study facilitators serve as knowledge brokers within the shared project boundary problem and solution space, and guide and support the interdisciplinary team. Knowledge brokers are weakly linked to all participating communities of practice, yet are full members of none. | • Interdisciplinary Team Leader (Knowledge Broker) (e.g. HI-U Specialist, #16)<br>• Prototyping Workshop Facilitator<br>• Expert Review Facilitator<br>• Usability Testing Evaluator<br>• Beta Testing Evaluator<br>• RCT Researcher and Evaluator |
| **Health Behavioural Intervention Community** | Team members adopt a health and intervention design, development and evaluation perspective of the shared problem and solution boundary space, focusing on intervention related theory and evidence-based strategies and content. | • Health Psychologist<br>• Health Behaviour Change Intervention Designer<br>• Physical Activity Expert<br>• Exercise Scientist<br>• Personal Trainer |
| **Information Systems Community** | Team members adopt a digital technology and software design, development and evaluation perspective of the shared problem and solution boundary space, focusing on the interactive mobile app design features. | • Information Systems Analyst<br>• Information Systems Designer<br>• Smartphone App Designer<br>• Human-Computer Interaction Designer<br>• User Experience Design Expert<br>• Mobile and App Software Engineer |
| **Business and Product Development Community** | Team members adopt a business and commercial perspective of the shared problem and solution boundary space, focusing on consumers, products, and business, marketing and financial models. | • Business Analyst<br>• Consumer Market Analyst<br>• Product Designer<br>• Consumer App Marketing Specialist<br>• Consumer App Monetisation Model Manager |

| | | |
|---|---|---|
| **Computer Sciences Community** | Team members adopt a technical build and programming perspective of the mobile app within the shared problem and solution boundary space, focusing on data structures and algorithms, hardware, infrastructure, architecture, networking, programming, and privacy and security. | • Mobile App Developer<br>• Information Architect<br>• Open-Source Software Consultant<br>• Data analyst<br>• DevOps Engineers<br>• Privacy Expert<br>• Security Expert |
| **Persuasive Technology and Game Development Community** | Team members adopt persuasive behavioural change and gamification perspectives of the shared problem and solution boundary space, focusing on the integration of persuasive and gamified strategies and design features. | • Persuasive Systems Software Designer<br>• mHealth Behavioural Change Support System Designer<br>• Game Designer<br>• Game Developer |
| **Third Party Stakeholders** | The interdisciplinary team may call upon, contract, partner or consult with a variety of third party stakeholders at various steps or activities of the project process. Indirect participatory involvements and contributions are offered for specific purposes. | • Physical Activity Expert Consultant<br>• Health Behaviour Change Intervention App Researcher<br>• Mobile App Developer Consultant<br>• Data Analytics Consultant<br>• DevOps Engineer Consultant |
| **End Users**<br><br>**(Target Population Group Representatives)** | Sample representatives of the defined target population group may (1) directly or (2) indirectly collaborate and engage with the interdisciplinary team during various steps or activities of the project process. Direct end users form part of the interdisciplinary team. Indirect end users remain bounded outside the interdisciplinary team boundary. | • Indirect end user sample representative group for iterative prototype design-test-refine sessions<br>• Indirect end user sample representative group for usability testing<br>• Direct end users as team members involved in collaborative participatory/co-design processes |

## 7.3.2 Actors: Application

### 7.3.2.1 Actors: Interdisciplinary Team Support Objects and Guidelines

***A Proposed Interdisciplinary Collaborative Team Member and Perspectives Template***

An interdisciplinary collaborative team member and perspectives template should be developed during the project and team formalisation process (Step 1 in the *"interdisciplinary collaborative process"*, Table 7.1), and provides insight into the heterogeneous team members' diverse community perspectives, approaches/methods, theories and practices. The template aims to deter team members from developing false assumptions and misinformed conceptions, and discounting and invalidating other team members' relevant and meaningful contributions to the design, development and evaluation of mHealth intervention apps. A more detailed explanation and example of the template in the context of a mHealth physical activity behaviour change intervention app project is provided in Appendix J.2.

***Proposed Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams***

High-performing interdisciplinary collaborating team performance is indispensable to the success of a mHealth (physical activity) behaviour change intervention app project (Mummah, et al., 2016; Blandford, et al., 2018). Good interdisciplinary collaborative teamwork is built on solid foundations of communication, coordination, cooperation and cohesion (Nancarrow, et al., 2013; Lopez, et al., 2018). Appendix J.3 provides ten guideline recommendations for high-performing interdisciplinary collaborating teams to reference, covering elements of: team membership and diversity; team leadership; team communication; team culture; individual team member attributes; team willingness and commitment; team training and development; conceptual teamwork; practical teamwork; and materials supporting teamwork.

### 7.3.3 Actors: Summary and Interdisciplinary Team Boundary Objects

Section 7.3 has provided a clipping (Figure 7.3) and detailed perspective (Figure 7.4) of the proposed Interdisciplinary mHealth App Design Framework's first main *"actors"* component. Corresponding to Figure 7.4, Table 7.2 has provided clear descriptions of the *"interdisciplinary team"*, *"third party stakeholder"* and *"end user"* actors, with examples (detailed descriptions in Appendix J.1). To effectively apply the *"actors"* component in practice, an *Interdisciplinary Collaborative Team Member and Perspectives Template* (Appendix J.2) and *Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams* (Appendix J.3) have been proposed.

Overall, these six *"actor"* component contributions can be employed by mHealth intervention app project teams to serve as boundary objects for assisting the interdisciplinary collaborative team's formation and formalisation (Step 1 in the *"interdisciplinary collaborative process"*, Table 7.1). In other words, the proposed two figures (diagrams) and four tables (templates) can be referenced and adapted by interdisciplinary collaborating teams to serve as common reference points for forming and formalising project teams (Star and Griesemer, 1989; Carlile, 2004; Star, 2010). This demonstrates their potential as boundary objects around which heterogeneous team members can communicate, share knowledge, translate, negotiate and adapt their respective community of practice and actor roles in relation to any given mHealth (physical activity) behaviour change intervention app project, interdisciplinary collaborative process, and (consumer app) product context. On a final note, the discussions in Section 7.3

have further unveiled and described the complex and intricate pragmatic sociomaterial and relationship entanglements between the proposed framework's four main *"actors"*, *"process"*, *"boundary objects and supporting artefacts"* and *"knowledge"* components, as well as the two supplementary *"project boundary"* and *"outcomes"* components (Figure 7.2).

## 7.4 The Interdisciplinary Collaborative Process

### 7.4.1 The Interdisciplinary Collaborative Process: A Detailed Perspective

Figure 7.5 provides a clipping of the "*interdisciplinary collaborative process*" component from Figure 7.2, which as discussed in Subsection 7.2.1.2, pertains to the pragmatic, processual and activity aspect of the proposed framework. In honing in on the process component of Figure 7.5, Figure 7.6 presents a more detailed perspective of the "*interdisciplinary collaborative process*" and its nine constituting steps (and comprising activities). This proposed process can be referred to, employed and flexibly adapted and applied by *"interdisciplinary teams"* (*"actors"* component) when designing, developing and evaluating mHealth (physical activity) behaviour change intervention consumer apps targeting individuals at the dual intra-interpersonal socioecological levels of health promotion.

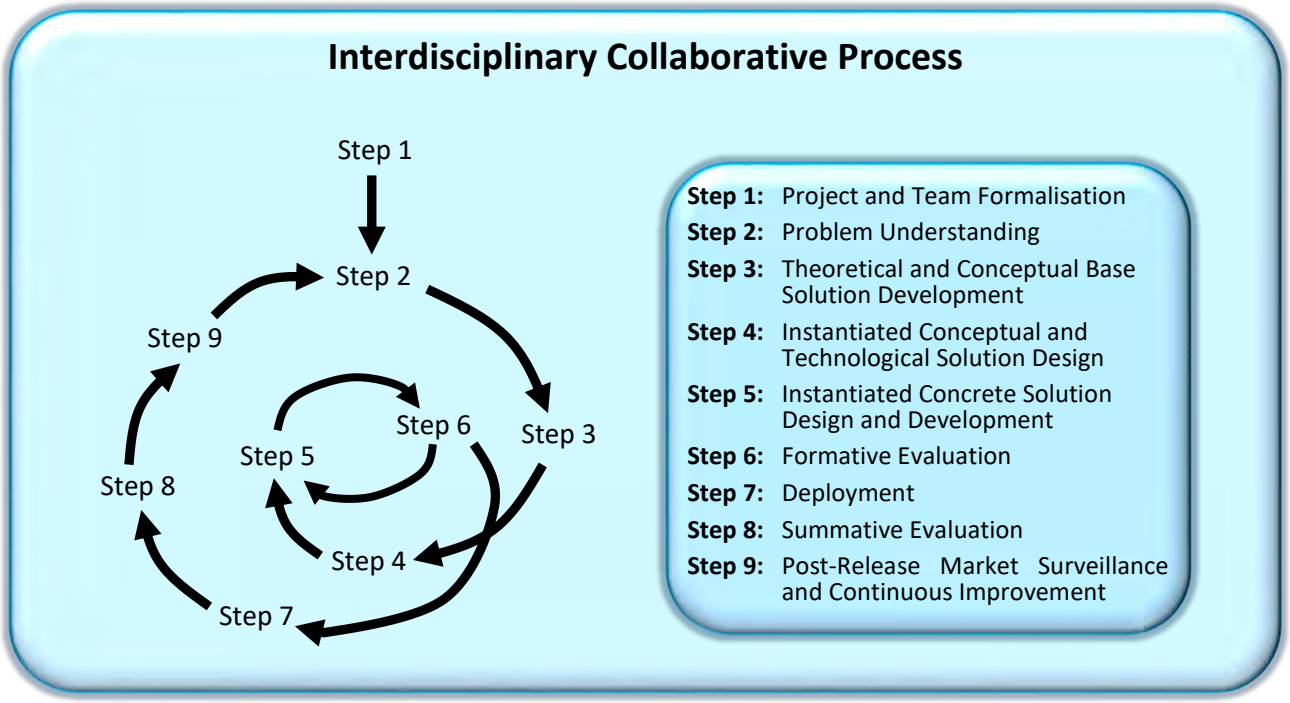



*Figure 7. 5: "Interdisciplinary Collaborative Process": Main Component 2 of the Proposed Framework [Source: Researcher's own construction]*

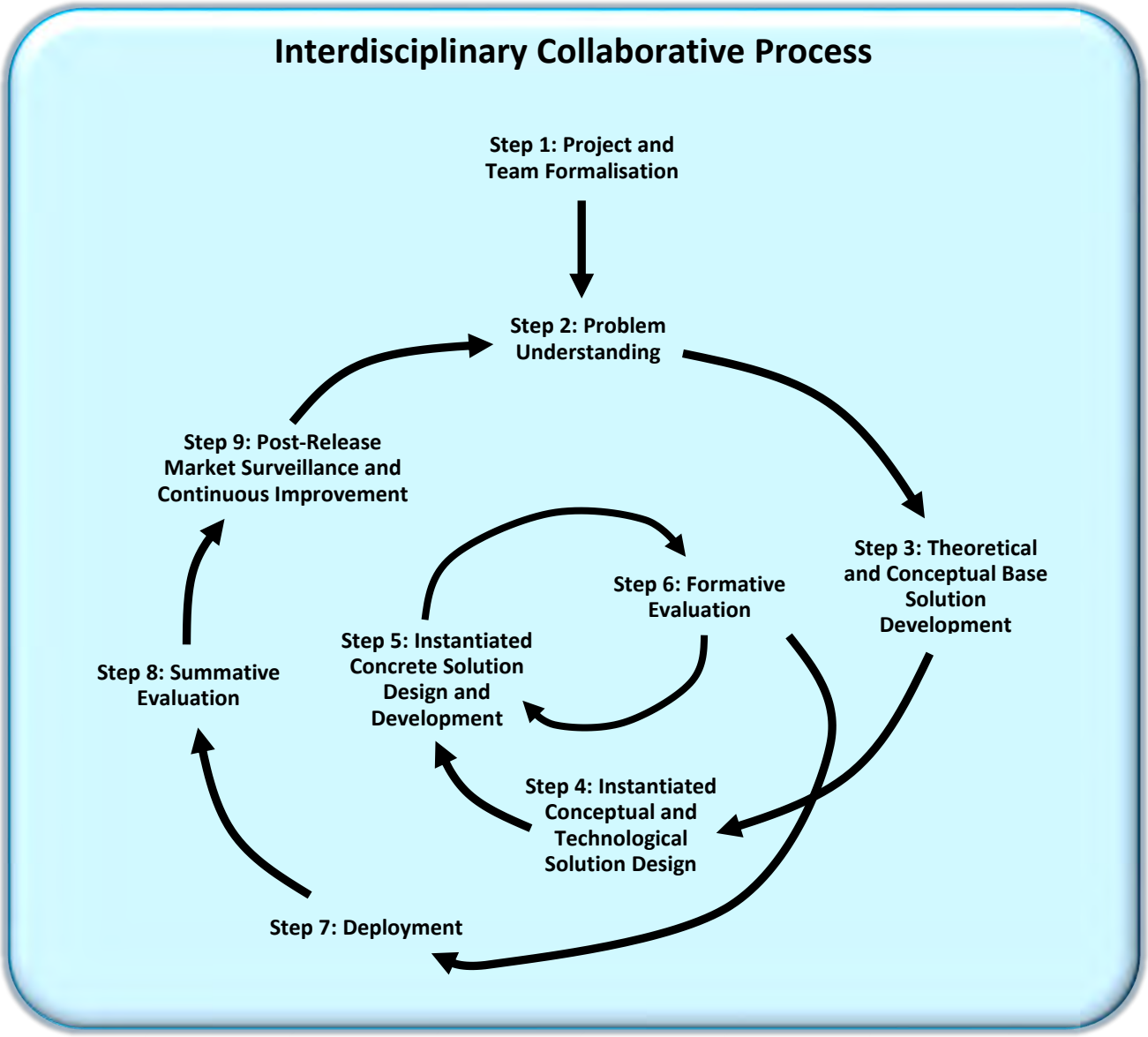



*Figure 7. 6: "Interdisciplinary Collaborative Process" Detailed Perspective: Main Component 2 of the Proposed Framework [Source: Researcher's own construction]*

Important to emphasise is that while the *"interdisciplinary collaborative process"* seems to exhibit a strict instructional prescriptive demeanour, it is intended to propose a comprehensive and general – and not a rigid or inflexible – prescriptive guideline for interdisciplinary teams to refer to, adapt and particularise to suit the contexts of their specific mHealth (physical activity) behaviour change intervention app projects. In other words, the process can be flexibly adjusted, modified and contextualised to fit the interdisciplinary team members' knowledge, expertise, skills and experience, as well as the defined project and product goals. Two additional justifications for the process's malleability were stipulated in Subsection 7.2.1.2.

A further key explanation for proposing a flexible interdisciplinary process concerns a caveat often evidenced in design process and artefact research, specifically the "discrepancy between

principles and practice" (Bertelsen, 2000, p.23) or the tensions and "contradictions between prescription and praxis" (Bertelsen, 1998, p.59). This is to say that there is usually a "mismatch between the prescriptions of the method [or process] and the actual design [or development] work" (Bertelsen, 1998, p.58). This mismatch can also be understood as a divergence between the "meaning" (that is, the literal prescription) and the "sense" (that is, the actual pragmatic use) of the proposed interdisciplinary collaborative process (Bertelsen, 2000, p.23). The way an interdisciplinary process is intended for use in practice is often very different to the way it is actually used in practice, because the team members' symbolic interactionist and cognitive interpretations of meaning and how they make sense of the process and apply it in collaborative concrete execution can vary greatly, depending on the situational context and circumstances (Bertelsen, 2000; Filip, 2016).

For these reasons, it cannot be expected that a proposed interdisciplinary collaborative process prescribe practice in a direct manner, nor can it determine produced product output (that is, it cannot be deterministic) (Bertelsen, 1998). Metaphorically speaking, the prescriptive (albeit flexible, adaptable and malleable) nature of the process's steps and activities can be described as "seeds" that grow and crystallise through the interdisciplinary team members' collaborative sociomaterial, symbolic interactionist and concrete pragmatic praxes (Bertelsen, 2000, p.23). The "actual" way (Bertelsen, 2000, p.23) a process's prescriptive "seeds" (steps and activities) will grow and crystallise in concrete practice depends on several factors, including the team members' worldview paradigms, perspectives and frameworks, their disciplinary (community of practice) knowledge, skills, expertise and experience, and the (design) boundary objects and support artefacts they employ in various contexts and situational circumstances. Moreover, the "actual" enactment and sensemaking of a proposed prescriptive process in adapted mHealth intervention app context and project application is influenced by the heterogeneity, political and power dynamics and individuality of the interdisciplinary collaborating team members.

Given this warranting, the interdisciplinary collaborative process proposed in this framework intends to strike a balance between providing a pre-determined (somewhat prescriptive) collaborative guideline structure, while simultaneously catering for situational and contextual malleability, interpretive flexibility and plasticity. These qualities quintessentially convey the *"interdisciplinary collaborative process"* as a secondary boundary object that interdisciplinary teams can refer to, employ, adapt and apply when carrying out praxes within the boundary of a given mHealth intervention app project (Star and Griesemer, 1989; Lee, 2007; Sander,

Nolwenn and Céline, 2019). In addition to these points and justifications, as discussed in Subsection 7.2.1.2, the interdisciplinary collaborative process also possesses several characteristics and qualities pertaining to its nature and its nine comprising steps.

### 7.4.2 The Interdisciplinary Collaborative Process: Characteristics and Nature

The *"interdisciplinary collaborative process"* possesses two key characteristics: (1) its *interdisciplinary* characteristic, and (2) its *collaborative* characteristic. In addition to these characteristics, the process possesses several key qualities (identified in Section 7.2.1.2). The characteristics and nature of the process are informed by literature and the findings from the critical thematic and comparative theoretical analysis (Chapter 6, Subsection 6.5.4).

#### 7.4.2.1 Characteristics of the Interdisciplinary Collaborative Process: Employing the Term "Interdisciplinary"

The term *"interdisciplinary"* is employed, rather than alternative "crossdisciplinary", "multidisciplinary" or "transdisciplinary" phrasing, for a few reasons. Firstly, in terms of terminological descriptions, interdisciplinary teamwork aims to integrate, blend and synthesise diverse disciplines' concepts, theories, approaches, methods and tools in order to address shared complex problems and achieve shared goals through holistic views (Jensenius, 2012). Secondly, in interdisciplinary teamwork, the disciplinary (community of practice) boundaries overlap (as illustrated in Figures 5.4, 5.5, 5.6, 5.7, Chapter 5), creating the need for ongoing active collaboration where social integration, project management and communication, negotiation and political power dynamics are introduced into shared processes and heteropraxial activities (Choi and Park, 2006; Jensenius, 2012). Thirdly, although initially described during its inceptive years as multidisciplinary, literature in recent years increasingly refers to the digital health and mHealth behaviour change intervention app arenas as interdisciplinary fields of study (Blandford, et al., 2018; Arigo, et al., 2019; Blandford, 2019a; 2019b; Sellak and Grobler, 2020; Sucala, et al., 2020; Sucala, et al., 2021), particularly in terms of physical activity apps (McCallum, 2019). Fourthly, while the critical analysis findings demonstrate oscillating shifts between various descriptions of multidisciplinary and interdisciplinary knowledge, theories, processes and praxes in mHealth intervention app research and real world practice, a general trend towards nurturing and growing an interdisciplinary knowledge base is evident. Further elaborations on these justifications for employing the *"interdisciplinary"* term are discussed in Appendix K.1.

#### 7.4.2.2 Characteristics of the Interdisciplinary Collaborative Process: Employing the Term "Collaborative"

The mHealth (physical activity) behaviour change intervention app design, development and evaluation process is largely recognised as needing to be *"collaborative"* in nature (Knittle, et al., 2016; Mummah, et al., 2016; Blandford, et al., 2018; Peiris, Miranda and Mohr, 2018; Van Gemert-Pijnen, et al., 2018; Arigo, et al., 2019; McCallum, 2019; Torous, et al., 2019; Walsh and Groarke, 2019; Sellak and Grobler, 2020; Sucala, et al., 2020; 2021). Good interdisciplinary collaborative teamwork is built on solid foundations of communication, coordination, cooperation and cohesion; concepts described in Appendix J.3 (Nancarrow, et al., 2013; Lopez, et al., 2018). A collaborative processual characteristic is concordant with interdisciplinary teamwork, particularly considering that it fosters knowledge sharing and encourages co-definition, co-creation, co-design, co-development, co-implementation and co-evaluation activities, which are prime examples of pragmatic and sociomaterial collaborative processes and practices in mHealth intervention projects (Thabrew, et al., 2018; Verbiest, et al., 2018; Walsh, et al., 2019), and mHealth physical activity app projects (Simmich, et al., 2021).

Notably, while high performing interdisciplinary team collaboration can be a challenging task (Koskela, et al., 2016; Lopez, et al., 2018), particularly considering it requires team members to be "willing to" collaborate (Melville-Richards, 2015, p.296) and often leads to trade-offs (Carlile, 2002; 2004), it can also develop a sense of shared ownership and responsibility between collaborating team members, which is integral for effective project, process and product success (Matilainen, et al., 2018). Ensuring that all team members possess a willingness to collaborate is necessary to acknowledge and clarify from project commencement, and is specified in the interdisciplinary collaborative team member and perspectives template (Appendix J.2, Subsection 7.3.2.1).

#### 7.4.2.3 The Nature of the Interdisciplinary Collaborative Process

The *nature* of the interdisciplinary collaborative process was briefly introduced in Subsection 7.2.1.2, in reference to Figure 7.2, and is elaborated on in this subsection in relation to Figure 7.6. The interdisciplinary collaborative process nature can be disserved in terms of its (1) *structure*, (2) *iterative flexibility*, and (3) *quality*.

Firstly, in terms of *structure*, the interdisciplinary collaborative process assumes a *somewhat systematic* and *non-linear* nature. As described in Section 7.4.1 above, the process should be

sufficiently logical, planned and organised, but need not be applied in a strictly prescriptive and unwavering methodical manner without consideration for the team's composition, the product objectives and the project context. The process steps and activities also need not be applied in a rigid instructional and orderly sequence, and instead can be executed in a manner that allows for non-linear flexibility and cyclical iterations, again depending on the team, project and product particulars. Non-linearity is more suited to complex, wicked design problem and solution spaces requiring innovation (Chen, 2019), and therefore the team should aim to strike balance between a somewhat systematic and non-linear interdisciplinary collaborative process structure, without hindering flexibility and innovation.

Secondly, the *iterative flexibility* of the interdisciplinary collaborative process is demonstrated by the nine crescent-like arrows between Steps 2 and 9 (Figure 7.6), which caters for an *agile*, *cyclical, feedback looping*, *continuous*, *adaptive*, *reflective* and *reflexive* process nature. While agile methodologies primarily originate from the information systems and software engineering disciplines, they are particularly well suited to the mHealth behaviour change intervention app environment, and have been increasingly adopted and applied in recent years (Jacobs and Graham, 2016; Edwards, et al., 2018; Thabrew, et al., 2018; Wilson, et al., 2018; Mala, 2019; Hermsen, et al., 2020; Sucala, et al., 2020). Agile, cyclical, feedback looping, continuous, adaptive, reflective and reflexive process qualities also allow mHealth intervention apps to be continuously tracked, monitored, tested, updated and released over time, which is imperative for consumer app products to be successful in the digital mHealth environment (Francis, 2017; Tozzi, 2017; Taylor, 2018; Mala, 2019). Furthermore, the flexible iterative cyclical feedback loops allow project teams to cycle back to specific steps or activities of the process, or to reiterate the process as whole, when necessary and desired (Edwards, et al., 2018; Hermsen, et al., 2020). Moreover, smaller and faster cyclical feedback loops are generally common practice in the process of designing, developing, testing and refining mHealth intervention app prototypes (Wilson, et al., 2018), and generally fall within Steps 5 (alpha testing), 6 (beta testing) and 9 (continuous improvements, delta testing) of the proposed interdisciplinary collaborative process (Figure 7.6). Notably, one exception to the iteratively flexible and agile nine crescent-like arrows between Steps 2 and 9 is the straight arrow from Steps 1 to 2 (Figure 7.6), which conveys a more stable nature where a project's and team's formation and formalisation is generally established and clarified as a solid base foundation before the subsequent steps and activities are carried out.

Thirdly, in terms of quality, the interdisciplinary collaborative process ought to be sufficiently *theory-based* and *evidence-based*. This means that the process steps and activities should be informed by valid, credible and reliable theory and empirical scientific evidence. In addition, it is suggested that frameworks, models, tools, techniques, objects and artefacts employed and utilised by the team during the interdisciplinary collaborative process ought to be theory-based and evidence-based. Examples of such frameworks and models include the BCW, COM-B Model, TDF, PSDM and the CALO-RE, BCT v1 and DHI taxonomies – all of which are acronyms described in the critical theoretical analysis findings (Chapter 6, Sections 6.5.3 and 6.5.5). Elaborated descriptions of the *"interdisciplinary collaborative process"* nature and the definitions of specific terms, such as "systematic", are provided in Appendix K.2.

### 7.4.3 The Interdisciplinary Collaborative Process Steps and Activities

The proposed *"interdisciplinary collaborative process"* comprises nine steps; outlined in Table 7.1 and illustrated in Figures 7.2, 7.5 and 7.6. The proposed nine steps and their encompassing activities are informed by the critical theoretical analysis findings (Chapter 6 and Appendix I), the landscape and context literature chapters (Chapters 3 and 4), and additional literature that references specific activities and more recent approaches (published subsequently to the critical analysis sample selection process, such as Sucala, et al., 2020). Table 7.3 describes each of the nine process steps and activities. The nine process steps are: (1) *project and team formalisation*; (2) *problem understanding*; (3) *theoretical and conceptual base solution development*, comprising sub-steps (3.1) *theoretical base* and (3.2) *conceptual base*; (4) *instantiated conceptual and technological solution design*; (5) *instantiated concrete solution design and development*; (6) *formative evaluation*, comprising sub-steps (6.1) *pilot testing* and (6.2) *beta testing*; (7) *deployment*; (8) *summative evaluation*; and (9) *post-release market surveillance and continuous improvement*. For purposes of length, Table 7.3 has been condensed. Appendix K.3 provides a more comprehensive and detailed table describing the activities, along with some examples relevant to the mHealth physical activity (promotion) behaviour change intervention app project and dual intra-interpersonal socioecological contexts, and reference citations.

*Table 7. 3: Interdisciplinary Collaborative Process Steps and Activities [Source: Researcher's own construction]*

| **Interdisciplinary Collaborative Process Step Number and Title** | |
|---|---|
| **Process Step Description** | **Process Step Activities and Descriptions** |
| **Step 1: Project and Team Formalisation** | |
| The mHealth intervention app project and interdisciplinary team are established and formalised. Business, interdisciplinary process plan, common knowledge base and partnership agreements are formalised. | • Develop project plan, business plan and model (including business model, monetisation model, competitor analysis, consumer market analysis, marketing model)<br>• Elect a Team Leader, Project Manager, Primary Empirical Study Facilitators and relevant heterogeneous General Team Members (*"actors"* Component)<br>• Formalise third party stakeholder agreements and identify target population group (*"actors"* Component)<br>• Co-develop a shared interdisciplinary collaborative process plan (*"process"* Component)<br>• Co-develop a common shared syntactic and semantic knowledge base (e.g. lingua franca; common glossary)<br>• Co-develop and formalise project, business and team documentation |
| **Step 2: Problem Understanding** | |
| The health problem, target health behaviour, target population group, digital platform and contextual factors are assessed, explicated and co-defined. | • Define the health problem (in behavioural terms), context and target population group (*"Actors"* Component)<br>• Select the (broad) target behaviour and specify the (refined) target behaviour<br>• State the broad intervention aim (in behavioural terms and digital terms)<br>• Conduct needs assessments for the health and target behaviour, the target population group (including psychosocial needs), and the digital technology (app) platform.<br>• Identify at-risk factors and modifiable determinants<br>• Co-create a shared Logic Model of the Problem<br>• Describe human factors and user interaction and experience preferences<br>• Co-define and document a shared understanding of the problem space |
| **Step 3: Theoretical and Conceptual Base Solution Development** | |
| **Step 3.1: Theoretical Base** | |
| The health behaviour change intervention and digital technology (and user interaction) aims, objectives and scope are co-defined and specified. | • Specify mHealth intervention app theme, subthemes and scope<br>• State health behavioural outcomes, intervention (clinical) aims and user interaction (usage) aims<br>• Specify the performance objectives for the intervention and user interaction<br>• Select relevant intra-interpersonal behavioural change determinants and correlates<br>• Specify change objectives and co-create change objective matrices for the intervention and user interaction<br>• Co-create a shared Logic Model of Change<br>• Co-create a mHealth intervention app value map with mHealth stories<br>• Co-develop a theoretical base solution document for the mHealth behaviour change intervention app |
| **Step 3.2: Conceptual Base** | |
| The theory and evidence-based strategies, methods, standards and guidelines are specified as practical strategy applications. The shared visions of the theoretical base and conceptual base are co-developed. | • Select and incorporate relevant mechanisms of change, BCTs, standards, guidelines and codes of practice<br>• Select appropriate gamification techniques and persuasive design principles, and link them with the BCTs<br>• Conceptually translate and operationalise selected mechanisms of change, BCTs, standards, guidelines, codes of practice, gamification/persuasive principles into practical strategy applications; co-create linkage matrices<br>• Co-formulate guiding principles (intervention core design objectives and key features)<br>• Clarify users' app design preferences and revise mHealth stories<br>• Co-develop high-level diagram of intervention components, sequence and user flow<br>• Co-produce a shared vision (common solution) document for the mHealth behaviour change intervention app |
| **Step 4: Instantiated Conceptual and Technological Solution Design** | |
| The theoretical and conceptual base solution is translated and operationalised into an instantiated co-conceptualised and co- | • Collaboratively generate and prioritise creative, innovative conceptual mHealth intervention app design ideas<br>• Translate and operationalise the practical strategy applications into digital and technical (app) features<br>• Further revise mHealth stories (Ben-Zeev, et al., 2015)<br>• Specify BIT elements (the software interface app design features) and define technical characteristics<br>• Specify BIT elements (the software interface app design features) and define technical characteristics |

| | |
|---|---|
| developed digital platform mHealth intervention app design solution. | • Co-create BIT-Tech framework and diagram, and illustrate BIT elements workflow<br>• Co-create complex (translation and operationalisation) instantiation matrices<br>• Co-create a shared Final mHealth Intervention App Logic Model<br>• Co-design low-fidelity conceptual instantiation mHealth intervention app design solutions<br>• Refine mHealth intervention app design instantiation components, sequence, user flow(s) and workflows<br>• Collaboratively update and refine guiding principles<br>• Co-develop a shared design vision document detailing the conceptual and technological mHealth behaviour change intervention app design solution<br>• Co-develop a preliminary interdisciplinary team plan for guiding the instantiated concrete solution design and development process (to be carried out in Step 5) |
| **Step 5: Instantiated Concrete Solution Design and Development** | |
| Iterative prototyping and usability design-test-refine cycles are performed to produce a co-designed and co-developed (nearly fully functional) MVP alpha mHealth intervention app. | • Review and formalise the interdisciplinary team's collaborative instantiated concrete solution design and development process and work plan<br>• Collaboratively conduct a series of iterative low-, medium- and high-fidelity prototyping cycles to co-develop and co-refine MVP alpha mHealth behaviour change intervention app prototypes<br>• Collaboratively conduct testing sessions (through usability testing, user experience testing and alpha testing), gather feedback and co-produce shared documentation detailing the iterative prototyping cycles, testing results and app alpha app revisions<br>• Co-refine the mHealth stories<br>• Collaboratively produce a co-designed and co-developed MVP (near-fully functional) alpha mHealth behaviour change intervention app (app prototype)<br>• Co-develop a preliminary interdisciplinary collaborative team plan for guiding the pilot/feasibility testing and beta testing formative evaluation processes (to be carried out in Steps 6.1 and 6.2, respectively) |
| **Step 6: Formative Evaluation** | |
| **Step 6.1: Pilot Testing** | |
| Pilot and feasibility tests are (iteratively) performed to co-produce a refined (fully functional) alpha mHealth intervention app. | • Review and formalise the interdisciplinary team's collaborative pilot testing process and work plan<br>• Select appropriate pilot and/or feasibility testing methods, measures and tools<br>• Collaboratively conduct pilot testing and/or feasibility testing sessions on the MVP alpha mHealth behaviour change intervention app prototype (may be iterative), gather feedback and co-produce shared documentation detailing the (iterative) pilot/feasibility testing cycles, test results and MVP alpha app solution revisions<br>• Collaboratively produce a co-developed and co-refined fully functional alpha mHealth behaviour change intervention app (app prototype)<br>• Collaboratively co-refine the preliminary interdisciplinary collaborative team plan for guiding the beta testing formative evaluation process (to be carried out in Step 6.2) |
| **Step 6.2: Beta Testing** | |
| Beta tests are (iteratively) conducted to co-produce a refined mHealth intervention app as a beta release candidate. | • Review and formalise the interdisciplinary team's collaborative beta testing process and work plan<br>• Select appropriate beta testing methods, measures and tools<br>• Collaboratively conduct beta testing sessions on the fully functional alpha mHealth behaviour change intervention app prototype (may be iterative), gather feedback and co-produce shared documentation detailing the (iterative) beta testing cycles, test results and alpha mHealth app solution revisions<br>• Collaboratively co-produce a refined mHealth behaviour change intervention app as a beta release candidate |
| **Step 7: Deployment** | |
| A deployment plan and business plan are co-produced for the mHealth intervention app's public commercial release. The beta release candidate is deployed to consumer app market stores. | • Co-produce a mHealth intervention app deployment plan for publicly deploying the beta release candidate on the commercial consumer app market<br>• Collaboratively review and update business plan, model and documentation, including the monetisation model, competitors analysis and plan, and the marketing plan<br>• Collaboratively co-produce deployment plan and deployment documentation, and co-review and update business plan, business model, monetisation model and business documentation. |

| Step 8: Summative Evaluation | |
|---|---|
| Summative evaluations are conducted on the beta release candidate to measure its quality, engagement, efficacy and effectiveness over time. A refined mHealth intervention app is co-produced and released on commercial consumer app market stores. | • Collaboratively co-produce a summative evaluation plan to evaluate the app's user engagement and intervention efficacy/effectiveness over a period of time<br>• Select appropriate summative evaluation methodologies (traditional or newly adapted)<br>• Select appropriate evaluation user app engagement methods and tools, and select and define appropriate measures and metrics (in alignment with the usage aims) (measures can be objective and/or subjective)<br>• Select appropriate evaluation intervention effect methods and tools, and select and define appropriate measures and metrics (in alignment with the clinical aims and health behavioural outcomes)<br>• Select appropriate summative evaluation reporting guidelines<br>• Collaboratively conduct summative evaluations on the mHealth intervention app beta release candidate<br>• Co-produce an updated and improved mHealth consumer app based on summative evaluation findings<br>• Co-produce shared documentation detailing the summative evaluations, findings and app updates/revisions |
| **Step 9: Post-Release Market Surveillance and Continuous Improvement** | |
| Subsequent to the mHealth intervention consumer app's public release on the commercial app market, continuous tracking, monitoring, maintenance, testing and improvement updates are executed over the remaining lifespan of the app. Business and monetisation analyses are performed, and project reports are published and disseminated. | • Collaboratively co-produce post-release market surveillance and continuous improvement strategies and plans for the remaining lifespan of the mHealth behaviour change intervention consumer app on the commercial app market. Strategies and plans concern the app's continuous tracking, monitoring, maintenance, testing and improvement updates, and the project's business, product, monetisation and consumer marketing models.<br>• Select and utilise appropriate (objectives and/or subjective) methods and tools for continuous tracking, surveillance monitoring, testing and improvement updates, including app analytics and error reporting.<br>• Collaboratively conduct continuous post-release market surveillance and continuous improvement activities on the publicly published mHealth behaviour change intervention app over the remaining project lifespan, and keep up-to-date on advancements in mobile digital technology and updates to app store policies/standards, aiming to continuously improve the app's innovation, user engagement and intervention effectiveness.<br>• Frequently review and update the business, monetisation and consumer marketing models and product strategy<br>• Co-produce shared documentation (for the app's remaining lifespan) detailing the post-release market surveillance and continuous improvement strategies, plans, activities, app analytics, feedback findings, error reportings, bug fixes and version updates.<br>• Co-produce, publish and disseminate mHealth intervention app project reports and findings (share across academic, industry, public and community spheres) |

### 7.4.4 The Interdisciplinary Collaborative Process: Application

#### 7.4.4.1 Guideline Recommendations for Applying the Interdisciplinary Collaborative Process

To reiterate, the proposed *interdisciplinary collaborative process* offers comprehensive and general, rather than strict and rigid, prescriptive guidance for teams to reference and use during a mHealth intervention app project. The pragmatic application of the process is flexible and customisable to different project, team and product objective contexts. It is at the discretion of the interdisciplinary team to deliberate whether certain steps and activities are performed iteratively, simultaneously, or disregarded. In light of the process's adaptability, it is imperative that interdisciplinary teams first clearly outline and define their particularised shared project process plan in Step 1, when formalising the project documentation. This is important because the shared interdisciplinary collaborative process serves as a boundary object and common reference point for guiding, directing and supporting team members' knowledge sharing practices and heteropraxial activities throughout the mHealth intervention app project lifespan.

In addition, it is important to consider how the political power dynamics and team members' positioning may influence the interdisciplinary team's "actual" enactment of a planned process in real world practice (Bertelsen, 2000, p.23; Iivari, 2019). This ties in with the need for team members to be aware and cognisant of the "discrepancy between principles and practice" (Bertelsen, 2000, p.10) and the tensions and "contradictions between prescription and praxis" (Bertelsen, 1998, p.59), in which case the planned (conceptual) process may be challenging to execute perfectly in actual (pragmatic) practice, requiring teams to be flexible and adaptable in the face of unanticipated challenges and deviations. Moreover, given the "young" (Mummah, et al., 2016, p.1), "emerging" (Taj, Klein and van Halteren, 2019, p.1), rapidly evolving and complexly interwoven nature of the mHealth intervention app arena, there remain knowledge gaps and there is no absolute or ideal prescriptive process that can strictly guide and support all interdisciplinary teams in every possible project and product context, and thus proposing a general, albeit flexible and adaptable, interdisciplinary collaborative process is befitting.

### 7.4.5 The Interdisciplinary Collaborative Process: Summary and Process Boundary Object

Section 7.4 has provided a clipping (Figure 7.5) and detailed perspective (Figure 7.6) of the proposed Interdisciplinary mHealth App Design Framework's second main *"interdisciplinary collaborative process"* component. Corresponding to Figure 7.6, the *"interdisciplinary"* and *"collaborative"* characteristics and several *"nature qualities"* of the process have been explained, and Table 7.3 has provided descriptions of the *"nine process steps"* and comprising activities (with more detailed descriptions, examples and references included in Appendix K.3). Furthermore, *"guideline recommendations"* have been proposed for applying the framework's process in practice.

Overall, the four *"interdisciplinary collaborative process"* component contributions can be employed by mHealth intervention app project teams to serve as boundary objects for assisting the interdisciplinary collaborative project formation and formalisation (Step 1, Table 7.3). In other words, the proposed two figures (diagrams) and two tables can be referenced and adapted by interdisciplinary collaborating teams to serve as common reference points for forming and formalising project process plans (Star and Griesemer, 1989; Carlile, 2004; Star, 2010). This demonstrates their potential as boundary objects around which heterogeneous team members can communicate, share knowledge, translate, negotiate and adapt process steps and activities to suit any given mHealth (physical activity) behaviour change intervention app project, team,

and (consumer app) product context. Moreover, the discussions in Section 7.4 have further uncovered the complex and intricate pragmatic sociomaterial and relationship entanglements between the proposed framework's four main *"process"*, *"actors"*, *"boundary objects and supporting artefacts"* and *"knowledge"* components, and the two supplementary *"project boundary"* and *"outcomes"* components (Figure 7.2). On a final note, the integral role of defining a clear and unambiguous process upfront as a foundational grounding, guiding and supporting framework component has been highlighted and is depicted in its positioning as the bottom (blue rectangle) base within the (yellow rectangle) *"project boundary"* (Figure 7.2).

## 7.5 Boundary Objects and Supporting Artefacts

### 7.5.1 Boundary Objects and Supporting Artefacts: A Detailed Perspective

Figure 7.7 provides a clipping of the "*boundary objects and supporting artefacts*" component from Figure 7.2, pertaining to the pragmatic artificial and sociomaterial aspect of the proposed framework. In honing in on the objects component of Figure 7.2, Figure 7.8 presents a more detailed perspective of the categories and types of "*boundary objects*" and "*supporting artefacts*" employed, utilised and created by interdisciplinary team members when carrying out process steps and knowledge sharing practices in mHealth (physical activity) behaviour change intervention app projects. The object and artefact example illustrations in Figures 7.7 and 7.8 are not exhaustive or strictly prescriptive (Appendix L.1). Boundary objects (the first subcomponent) are classified into three categories: (1) "*primary*", (2) "*secondary*", and (3) "*tertiary*". Each category comprises two types of boundary object: (1) "*design*" or (2) "*general*". Supporting artefacts (the second subcomponent) are grouped into three categories: (1) "*supporting methods*", (2) "*supporting guidelines, standards and codes of practice*", and (3) "*other supporting artefacts and materials*".

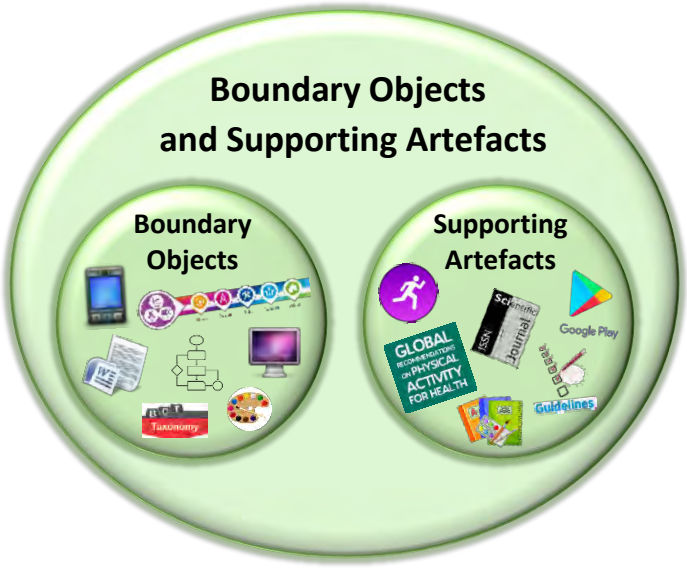





*Figure 7. 7: "Boundary Objects and Supporting Artefacts": Main Component 3 of the Proposed Framework [Source: Researcher's own construction]*

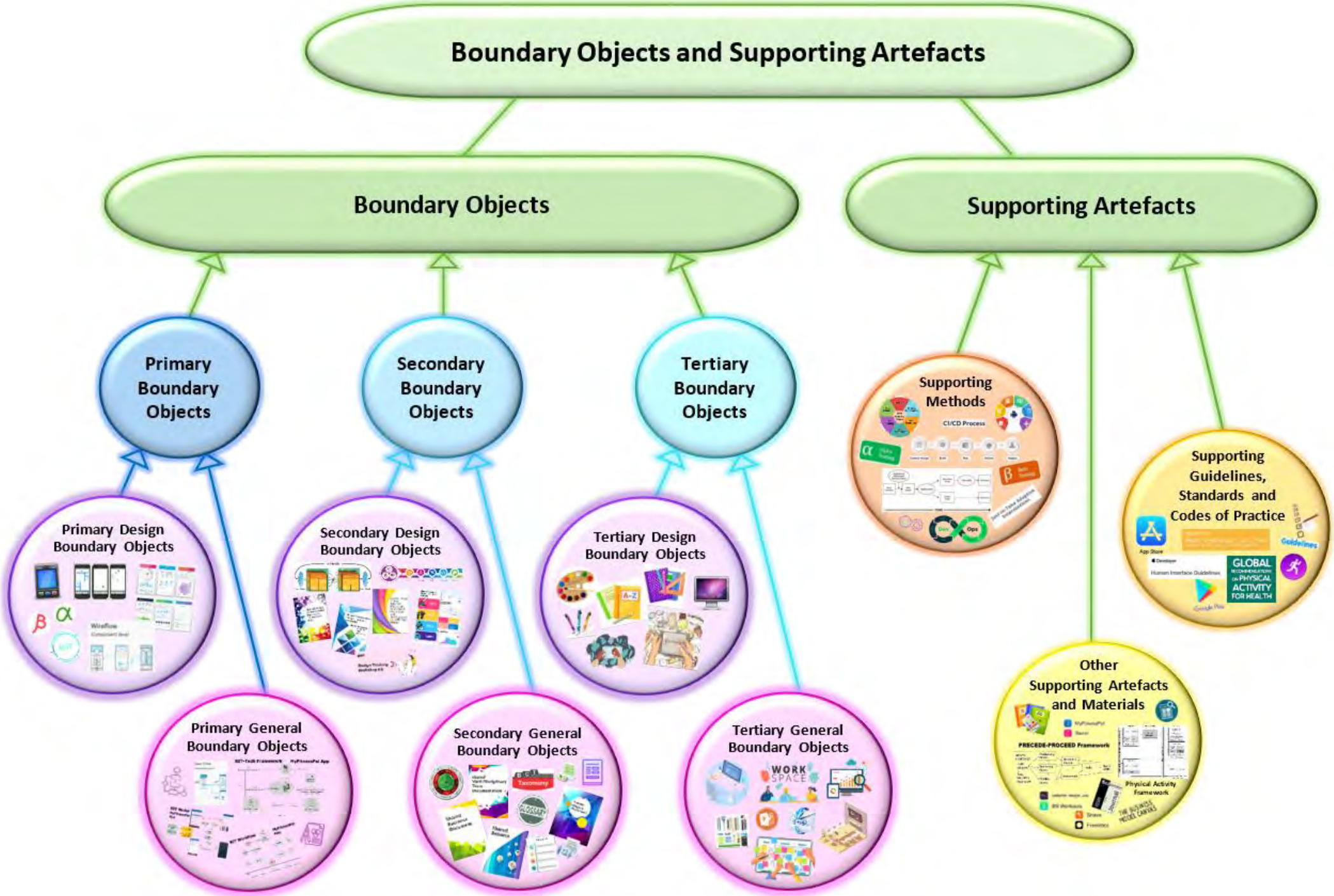



*Figure 7. 8: "Boundary Objects and Supporting Artefacts" Detailed Perspective: Main Component 3 of the Proposed Framework [Source: Researcher's own construction, object and artefact example icons clearly illustrated and identified in Appendix L.1]*

*"Boundary objects"* and *"supporting artefacts"* (Figures 7.7 and 7.8) are both forms of artefacts employed and utilised by interdisciplinary collaborating team members during any given mHealth intervention project and process, but are distinguishable based on their respective definitions, core properties, characteristics and nature qualities. *Artefacts* are any artificially constructed (and modifiable) tangible and intangible objects that are man-made, and conceptualised and theorised for human (actor) purpose, in order to achieve certain tasks, values or goals (Simon, 1996; Bowker and Star, 1999; Hevner and Chatterjee, 2010). Artefacts can exist along a continuum from tangible (physical, concrete and material) to intangible (conceptual, theoretical and abstract) forms (Garrety and Badham, 2001). For example, a mHealth physical activity app prototype is tangible, a shared interdisciplinary collaborative process plan is both tangible and intangible, and a design solution idea is intangible.

In information systems and DSR, the mental conceptualisation and pragmatic utilisation of artefacts are innately interwoven in the embodiment of design theory and design descriptive and prescriptive knowledge, and the (social, cultural and historical) crystallised value of artefacts are derived and realised through their practical use in real world symbolic interactionist and sociomaterial design situations and context settings (Vygotsky, 1978; Bertelsen, 2000; Vom Brocke, et al., 2020). Some artefacts hold truth value (for example, theories, causal hypotheses and empirical regularities) while other artefacts hold utile value (for example, terminologies, constructs, conceptual frameworks, taxonomies, product knowledge, process knowledge, method knowledge, practice guidelines) (Iivari, 2007; Hevner and Chatterjee, 2010); both of which are important for mHealth intervention app project activities. Their utile value, however, is generally not a sense of "prefabricated… 'thing'-ness" (Star, 2010, p.603), but instead derives from collaborating team members' actions toward, around and with artefacts in pragmatic enacted use and context (Wenger, 2010; Nicolini, Mengis and Swan, 2012). Their value is therefore realised through the constitutive temporal, spatial and contextual entanglement of the social and dialogical (actor) world and the material (artefact) world (Engeström, Engeström and Kärkkäinen, 1995; Akkerman and Bakker, 2011; Pikas, et al., 2018). Overall, artefacts can serve a multitudinous range of purposes, and play an essential role in guiding, mediating, facilitating and supporting interdisciplinary collaborating team members' various heteropraxial and knowledge sharing engagements throughout the mHealth intervention app project and process lifespan.

### 7.5.2 Boundary Objects

*"Boundary objects"* constitute the first aspect of the *"boundary objects and supporting artefacts"* component (Figure 7.8). *Boundary objects* are artefacts that serve as a means of translation and common point of reference for heterogeneous collaborating actors by fulfilling the information requirements and work processual needs of the several intersecting and interacting communities of practice in which they inhabit and "sit in the middle" of (Star and Griesemer, 1989, p.46; Star, 2010). Boundary objects are robust enough to offer a weakly structured common identify across practice communities, yet strongly structured for individual community use (Star and Griesemer, 1989). They may be abstract or concrete, and are organic (naturally emerging) or engineered (artificially nominated), malleable, sufficiently stable, gradually evolve over time through continuous reflection and reconfiguration, and become more meaningful through pragmatic actionised use in shared situational settings and particularised contexts (Star, 2010; Nicolini, Mengis and Swan, 2012; Abraham, 2015).

Essentially, as common reference points, boundary objects offer diverse collaborating actors a shared bridging basis for open engagement, communication, perspective-making, perspective-taking, mutual learning, cooperation, coordination, collaboration, negotiation, knowledge sharing and shared understanding, and in so doing, assist in the generation of innovative mHealth (physical activity) behaviour change intervention app design ideas and solutions (Broberg, 2011; Worrall, 2014; Koskela, et al., 2016). Moreover, design boundary objects in particular offer significant value in guiding, mediating and facilitating interdisciplinary collaborative design teamwork by supporting joint problem-solving and solution generating heteropraxial design and development activities, leading to the construction and production of innovative and enhanced hybrid mHealth intervention consumer app product solutions (Engeström, Engeström and Kärkkäinen, 1995; Bertelsen, 1998; 2000; Bergman, Lyytinen and Mark, 2007; Iivari, 2019).

#### 7.5.2.1 Boundary Objects: Core Properties

Interdisciplinary collaborating teams can distinguish between boundary objects from supporting artefacts by recognising whether the artefacts they employ, use and create meet the three core property criteria of boundary objects (Star and Griesemer, 1989; Star, 2010):

1. Interpretive flexibility;
2. The structure of informatic and work process needs and arrangements; and

3. The dynamic between ill-structured and more tailored uses.

Table 7.4 provides a brief description and examples of each core property, informed by boundary object theory (Chapter 5, Section 5.3.2), the critical theoretical analysis findings (Chapter 6, Section 6.5.5) and relevant literature. Appendix L.2 provides more detailed example explanations relevant to the mHealth physical activity behaviour change intervention app project context. Examples correspond to the example icons in Figure 7.8.

*Table 7. 4: Boundary Object Core Properties*

*[Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6), Star and Griesemer (1989), Henderson (1991; 1998), Carlile (2002), Eriksson (2008), Star (2010) and Bowker, et al. (2016)]*

| Property | Description | Examples |
|---|---|---|
| **Interpretive flexibility** | The object provides sufficient flexibility and recognisability across multiple practice communities by offering a common point of reference around which communication, coordination, cooperation, and collaboration can be mediated and facilitated while respecting and not compromising the diverse perspectives held different interdisciplinary team members. A specific object is interpreted differently by different team members/practice communities. | Interdisciplinary collaborating team members may have different interpretations of a *mHealth physical activity behaviour change intervention app prototype* and its encompassing app design features (example in *"Primary Design Boundary Objects"* in Figure 7.8).<br>For example, an information systems team member is likely to interpret app design features in terms of usability and user experience design, whereas a health behaviour intervention scientist is likely to interpret app design features in terms of intervention components and BCTs. |
| **The structure of informatic and work process needs and arrangements** | The object sufficiently reflects the necessary information requirements, needs and work practices, processes and arrangements to support interdisciplinary team members' cooperation, communication, coordination and collaboration. The shared material and organisational structure of the object provides an actionable passage point for information and work flows between collaborating team members, without hindering flexibility and innovation. | A common *"interdisciplinary collaborative process"* (proposed framework, main component 2) provides the interdisciplinary collaborating team with the structure of informatic and work process needs and arrangements (example in *"Secondary Design Boundary Objects"* in Figure 7.8).<br>A mHealth physical activity intervention app *design solution pattern template* (example in *"Primary Design Boundary Objects"* in Figure 7.8) contains the minimum necessary information and work practices applicable to an app's theoretical, conceptual and instantiated design solution. |
| **The a dynamic between ill-structured and more tailored uses (Plasticity)** | The object is plastic enough to provide team members with weakly unstructured joint use and highly structured localised use. In ill-structured form, the object offers a common point of reference for interdisciplinary translation, communication, coordination, cooperation and negotiation in joint collaborative activities. In strongly structured form, the object can be tailored for localised practice use. | *mHealth physical activity behaviour change intervention app sketches and wireframes* (examples in *"Primary Design Boundary Objects"* in Figure 7.8) are plastic enough to tack back-and-forth between offering team members with weakly or fairly unstructured joint (multiple community) use and strongly or highly structured localised (community-specific) use. |

### 7.5.2.2 Boundary Objects: Characteristics and Nature

In addition to meeting the three core property criteria for boundary objects, it is possible to distinguish boundary objects from supporting artefacts in terms of characteristics and nature qualities. The characteristics and nature qualities are informed by boundary object theory

(Chapter 5, Section 5.3.2), the critical theoretical analysis findings (Chapter 6, Section 6.5.5) and relevant literature.

***Characteristics of Boundary Objects***

Boundary objects possess key characteristics (attributes or descriptive qualities) that contribute their shared identity, pragmatic value and evolutionary maintenance in practice contexts and design settings (Wenger, 1998; Fong, Srinivasan and Valerdi, 2007; Broberg, 2011; Abraham, 2015). It is important that interdisciplinary teams manage boundary objects in terms of their core properties and characteristics in order to maintain their coherency and utile value across heterogeneous intersecting practice communities (Bowker and Star, 1999; Wohlrab, et al., 2018). Table 7.5 provides a template outlining sixteen characteristics (with examples): *abstractness*; *concreteness*; *plurality*; *neutrality*; *contextualisation*; *malleability*; *modularity*; *standardisation*; *flexibility*; *visualisation*; *accessibility*; *usefulness (or utility)*; *stability*; *annotation*; *up-to-dateness*; and *versioning (or traceability)*. Appendix L.3 provides more detailed descriptions and example explanations relevant to the mHealth physical activity behaviour change intervention app project context. Examples correspond to the example icons in Figure 7.8. Some characteristics exist along a continuum where the aim is to strike an adequate equilibrium balance between two respective characteristics, while other characteristics stand independently.

*Table 7. 5: Characteristics of Boundary Objects [Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6), Star and Griesemer (1989), Henderson (1991; 1998), Bowker and Star (1999), Carlile (2002), Fong, Srinivasan and Valerdi (2007), Star (2010), Broberg (2011), Abraham (2015), Lopez, et al. (2018), and Wohlrab, et al. (2018)]*

| Characteristic | Description | Examples |
|---|---|---|
| **Abstractness and Concreteness (Continuum)** | *Abstractness* offers high levels of generalised shared commonalities as symbolic, conceptual and non-specific representations. *Concreteness* offers detailed specificities as tangible, material and specific representations. | The *shared vision solution* for a mHealth physical activity behaviour change intervention app providing a high-level abstract and conceptual representation of the interdisciplinary team's common goal (example in *"Secondary Design Boundary Objects"* in Figure 7.8).<br>A *working mHealth physical activity behaviour change intervention app prototype* – in fully functional, tangible and material form – on a mobile device represents a concrete object (example in *"Primary Design Boundary Objects"* in Figure 7.8). |
| **Plurality and Neutrality (Continuum)** | *Plurality* incorporates and represents informatic and work needs, views, knowledge and interests of all heterogeneous practice communities. *Neutrality* maintains sufficient objectivity to maintain fairness in power status and negotiation dynamics. No object is completely objective. | An interdisciplinary team's shared *"interdisciplinary collaborative process"* (example in *"Secondary Design Boundary Objects"* in Figure 7.8) represents team members' different informatic and work process needs, yet is sufficiently neutral not disregard the power status and negotiation dynamics of team members when executing knowledge sharing practices and heteropraxial activities. |

| | | |
|---|---|---|
| **Contextualisation** | A designated artificially engineered boundary object can be adapted and particularised to fit the specific mHealth intervention app project, team and product context. | The *BIT Model*, *BIT-Tech Framework* and *BIT Workflow* (examples in *"Primary General Boundary Objects"* in Figure 7.8) can be adapted and particularised to fit a specific mHealth physical activity behaviour change intervention app project, team and product context. |
| **Malleability** | A boundary object can be adapted, modified and reconfigured over time, in response to new informatic requirements and work process needs and other knowledge related novelties. | A *mHealth physical activity behaviour change intervention app prototype* can be modified, revised and transformed over time (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). |
| **Modularity** | Team members can tend to particular elements or components of a boundary object without disturbing other members' use of the object. | Computer science team members (Figure 7.4) can tend to the technical details of a mHealth physical activity intervention app's design and development without disturbing other members (example illustration in *"Primary General Boundary Objects"* in Figure 7.8). |
| **Standardisation and Flexibility (Continuum)** | *Standardisation* is the skeleton architecture of an object that should remain sufficiently structured, while *flexibility* allows for contextualisation malleability, innovation and transformation. | The proposed interdisciplinary team's shared *"interdisciplinary collaborative process"* (example in *"Secondary Design Boundary Objects"* in Figure 7.8) provides a balance between standardisation and flexibility. |
| **Visualisation** | Object serves as a visual interface by providing virtual or physical graphical representations, enabling the mediation of dialogical and visually expressive exchanges and negotiations. | *Graphical user interface design sketches* of a mHealth physical activity behaviour change intervention app provide visual illustrations of the app's interface design features (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). |
| **Accessibility** | All interdisciplinary team members are aware of, informed about and able to access a boundary object when necessary, together with training material and practical application guidelines. | The *interdisciplinary team's shared documentation* and *guidelines recommendations* should be available and accessible at all times during a mHealth physical activity behaviour change intervention app project and process (examples in *"Secondary Design Boundary Objects"* and *"Secondary General Boundary Objects"* in Figure 7.8). |
| **Usefulness (or Utility)** | Object incorporates the minimum informatic requirements and work process needs of each community to be useful, providing vague yet accurate and good enough content. No boundary object is universally useful or intricately whole. | The *taxonomies* and *glossaries* created and utilised by the interdisciplinary team satisfies the minimum informatic requirements and work process needs and arrangements of each team member (examples in *"Secondary General Boundary Objects"* in Figure 7.8). |
| **Stability** | Object's skeleton architecture and infrastructure structure and information content is sufficiently stable over time while also allowing for gradual evolutionary malleability, flexibility, updates and versioning. | The skeleton structure and information content of a project's and team's shared *"interdisciplinary collaborative process"* should remain stable over time, while simultaneously allowing for revisions, updates and versioning changes (example illustration in *"Secondary Design Boundary Objects"* in Figure 7.8). |
| **Annotation** | The option to expand and add additional information and work arrangements to provide context for localised and tailored community-specific use. | Information systems team members (Figure 7.4) can add additional technical information to the *interaction user flow diagrams* of a mHealth physical activity behaviour change intervention app for localised use (example illustration in *"Primary Design Boundary Objects"* and *"Primary General Boundary Objects"* in Figure 7.8). |
| **Up-to-Dateness** | The informatic requirements and work process needs and arrangements should be up-to-date. Updates should be timely and communicated to all interdisciplinary collaborating team members. | The *shared design vision solution documentation on the theoretical, conceptual and instantiation app design* should be kept up-to-date, with version tracking (examples illustration in *"Secondary Design Boundary Objects"* in Figure 7.8). |
| **Versioning (or Traceability)** | Revisions and changes should be versioned and tracked over the object's evolution and lifespan. Versioning can use semantic numerical sequence-based identifiers, chronological and/or author references. | A mHealth physical activity behaviour change intervention app is versioned throughout its alpha and beta development stages, as well as after its public release on the commercial consumer app market (with minor and major updates) (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). |

### *The Nature of Boundary Objects*

Boundary objects generally exhibit several innate nature qualities throughout their lifespans, which influences the manner in which they behave and the various roles, forms and functionalities they assume when employed and utilised in diverse pragmatic sociomaterial context situations and settings of use (Bertelsen, 1998; 2000; Star, 2010; Nicolini, Mengis and

Swan, 2012). Table 7.6 provides a template outlining and describing nature qualities categorised in five groups (with examples): *a blurry nature*; *a transitional and dynamic nature*; *a shifting status and role nature*; *a fallible yet good enough nature*; and *an evolutionary nature*. Appendix L.4 provides more detailed descriptions and example explanations relevant to the mHealth physical activity behaviour change intervention app project context. Examples correspond to the example icons in Figure 7.8.

*Table 7. 6: Nature Qualities of Boundary Objects [Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6), Star and Griesemer (1989), Bowker and Star (1999), Carlile (2004), Engeström and Blackler (2005), Carlile (2006), Star (2010), Nicolini, Mengis and Swan (2012), Carlile, et al. (2013), Stoytcheva (2015), and Huvila, et al. (2016)]*

| Nature Quality | Sub-Nature Qualities and Description | Examples |
|---|---|---|
| **Blurriness** | A boundary object can simultaneously inhabit more than one category and type depending on the pragmatic manner in which interdisciplinary collaborating team members employ and use the object in particular contexts and actionised situational settings. | *Creative materials* such as paper, canvases, pens, colour pencils, glue, sticky notes, paints and paint brushes that inhabit the *"Tertiary General Boundary Objects"* and *"Other Supporting Artefacts and Materials"* non-design category types can fall into the *"Tertiary Design Boundary Objects"* category type when employed by interdisciplinary team members for specific design purposes in design situations and settings (Figure 7.8). |
| **Transitional and Dynamic** | **Category and type transitioning and dynamism**<br>A boundary object can transition (shift) from one category and type to another depending on the pragmatic manner in which interdisciplinary team members employ and use the object in particular contexts and actionised situational settings. | The *materials and artefacts constituting a mHealth physical activity behaviour change intervention app* may not form part of the *"Primary Design Boundary Objects"* category type until they are crystallised into the prototype form and sufficiently encapsulate the necessary informatic and work needs and enable cross-disciplinary translation (Figure 7.8). |
| | **Foreground and background transitioning**<br>A boundary object can transition (shift) from the background to the foreground (and vice versa) during different stages/activities of the project and interdisciplinary collaborative process, depending on the context of use and the team members' intentions, knowledge and experiences. | *Prototyping methods ("Supporting Methods"), CAD software ("Tertiary Design Boundary Objects") and design documentation ("Secondary Design Boundary Objects")* will be largely called upon by team members during Step 5 (Table 7.3) when creating low-, middle- and high-fidelity mHealth behaviour change intervention app prototype versions (Figure 7.8). |
| | **Knowledge capability transitioning and dynamism**<br>A boundary object can transition between, or inhabit more than one, knowledge boundary capability depending on sociomaterial constellation in which it is embedded and pragmatically utilised. | A mHealth physical activity behaviour change intervention app (*"Primary Design Boundary Objects"* in Figure 7.8) will encapsulate and embed syntactic, semantic and pragmatic design knowledge. |
| **Shifting Status and Role** | **Contextualised shifting status and role**<br>In relation to transitions and dynamism, the status and role of a boundary object can change depending on the sociomaterial constellation and context in which it is utilised, or if novelties are introduced. | The contextual status and role of an interdisciplinary collaborating *team's documentation* may change if new informatic requirements and work (situational or task) processes and activities are added (example in *"Secondary Design Boundary Objects"* in Figure 7.8). |
| | **Actor-related shifting status and role**<br>The status and role of boundary objects can shift depending on the community/disciplinary backgrounds, capabilities, experiences, knowledge, skills and expectations of the team members using them in practice, and may produce multiple different affordances and interpretations for different actors in different contexts. | The *output product (mHealth physical activity behaviour change intervention app)* produced using the exact same interdisciplinary collaborative process will differ depending on the team members' community (disciplinary) backgrounds, capabilities, experiences, knowledge, skills and expectations involved in its design, development and evaluation (example in *"Primary Design Boundary Objects"* in Figure 7.8). |

| | | |
|---|---|---|
| | **Relational shifting status and role**<br>A boundary object can shift in its status and role in relation or in response to other boundary objects. | A *method* or *framework* (examples in *"Secondary General Boundary Objects"* in Figure 7.8) shown to be more useful for serving specific practice purposes may replace another method or framework, causing it to lose status relevance and role positioning. |
| **Fallible yet Good Enough** | All boundary objects are fallible, neither catch-all or absolute/perfect solutions, and cannot be universally useful or provide magic bullet answers; objects can be vague yet provide a good enough roadmap to support collaboration. | The framework's proposed *interdisciplinary collaborative process* (framework main component 2, example in *"Secondary General Boundary Objects"* in Figure 7.8) (Section 7.4) does not provide a catch-all perfect solution to designing, developing and evaluating mHealth physical activity behaviour change intervention apps. It can be fallible if applied poorly, yet provides a vague and good enough roadmap to support interdisciplinary team collaboration. |
| **Evolutionary** | Boundary objects follow an evolutionary lifespan/career and are in the constant process of (re)making. They are messy and change depending on their sociomaterial use in practice. Lifespan revisions can lead to an object's growth and development or obsolescence/failure. | The early *MVP alpha version of a mHealth physical activity behaviour change intervention app* (Step 5 of the interdisciplinary process in Table 7.3) will change drastically by the time it becomes a successful beta candidate version for public release on consumer app market stores (Steps 7 and 8). Thereafter, through continuous improvements and updates, the app will continue to change (Step 9), until the team decides to stop updating and fixing it, leading to its obsolescence and failure. |

### 7.5.2.3 Boundary Objects: Three Categories and Two Types

#### 7.5.2.3.1 Three Categories of Boundary Objects: Primary, Secondary and Tertiary

As illustrated in Figure 7.8, boundary objects are classified into three categories, namely: (1) *primary boundary objects*; (2) *secondary boundary objects*; and (3) *tertiary boundary objects* (Wartofsky, 1979; Bertelsen, 1998; 2000; Garrety and Badham, 2001; Nicolini, Mengis and Swan, 2012; Filip, 2016; French, 2016; Huvila, et al., 2016; Matilainen, et al., 2018). The three categories represent subclasses of the superclass, boundary objects, illustrated by the three green inheritance arrows extending upwards from the "primary", "secondary" and "tertiary" categories into the overarching green shaded "boundary objects" subcomponent (Figure 7.8). The use of inheritance arrows is borrowed from information systems object-oriented analysis and design modelling notation (Wilson, 1995; Wazlawick, 2014). Wazlawick (2014, p.138) describes inheritance as useful for indicating when "a concept effectively has two or more subtypes". Wilson (1995, p.4) similarly explains inheritance notation as used to denote "a hierarchy of object types, subtypes, sub-subtypes, and so on". The three green inheritance arrows therefore convey the primary, secondary and tertiary boundary object categories (as subclasses/subtypes, depicted with dark blue, sky blue and light blue colour-outlined circles, respectively, Figure 7.8) as inheriting the core properties, characteristics, nature qualities, roles and functionalities of the boundary object (as a superclass).

***Primary Boundary Objects***

*Primary boundary objects* (left-positioned dark blue shaded circle in Figure 7.8) are artefacts that directly motivate and fuel the mHealth (physical activity) behaviour change intervention

app design, development and evaluation process, and are directly created and utilised by interdisciplinary collaborating team members during the interdisciplinary collaborative process (framework main component 2, Figure 7.2) (Nicolini, Mengis and Swan, 2012; Matilainen, et al., 2018). They are the central artefacts around which all productive praxis and collaborative activity is essentially organised and focused (Garrety and Badham, 2001), specifically the project and the mHealth (physical activity) behaviour change intervention app (including the evolutionary and iteratively constructed intermediate prototypes) (Filip, 2016). Primary boundary objects are direct mediators between the collaborating heterogeneous actors and the intended mHealth intervention app project and product outcome, and their primary nature triggers and drives knowledge exchanges and collaborative teamwork praxes across the different practice community boundaries during the project process (Tellioğlu, 2009; Nicolini, Mengis and Swan, 2012; Filip, 2016). Moreover, they serve as sources for sparking tensions and conflicts, which in turn drives interdisciplinary collaborating team members to engage in appropriately responsive negotiation and innovation practices (Bertelsen, 1998; French, 2016). The malleability of their features allows for transformation, continuous changes and iterative adaptations during the design, development and evaluation practices of the interdisciplinary collaborative process (Nicolini, Mengis and Swan, 2012).

A key primary boundary object example is the mHealth (physical activity) behaviour change intervention app (illustrated by the mobile device icon in *"Primary Design Boundary Objects"*, Figure 7.8), which quintessentially motivates and drives the project process and is continuously improved through several sociomaterial design-test-refine iteration cycles performed by the team. The app is the direct primary object (product) and objective of the mHealth intervention app project, and is the direct primary means through and around which the team structures their heteropraxial collaborative activities (Broberg, 2011; Nicolini, Mengis and Swan, 2012). The mHealth app ultimately emerges from the project and process as a co-produced and crystallised sociomaterial hybrid representation of the team's shared ideas, knowledge and collaborative activities.

***Secondary Boundary Objects***

*Secondary boundary objects* (centre-positioned sky blue shaded circle in Figure 7.8) are subsidiary artefacts that support and facilitate communication, cooperation, coordination, collaboration and production around primary boundary objects (Garrety and Badham, 2001; Matilainen, et al., 2018). Secondary boundary objects, like primary boundary objects, are

created and used by interdisciplinary teams during the interdisciplinary collaborative process (Garrety and Badham, 2001). However, in contrast to primary boundary objects, secondary boundary objects do not fuel, trigger or drive motivation for collaboration; instead, they enable, support, facilitate and mediate collaboration (Nicolini, Mengis and Swan, 2012). At times, they may even disrupt or impede interdisciplinary team collaborative work praxes if poorly designed or inappropriately applied within particular contexts and situational settings (Nicolini, Mengis and Swan, 2012). Secondary boundary objects are representations that support the preserving, transmitting and translating of human practices, skills and modes of action for carrying out productive process praxes, and generally incorporate the use of other mediating artefacts in order to execute modes of action and operation (Bertelsen, 1998). In addition, they bridge the flow of knowledge across heterogeneous practice community boundaries by enabling, facilitating and mediating communication and shared understanding, yet they do not encapsulate explanatory knowledge for how the diverse practice community boundaries arose or came about (Nicolini, Mengis and Swan, 2012). In short, they are mediators for shared action and knowledge translation and are representations for modes of acting on, with and around primary boundary objects (Wartofsky, 1979). Moreover, like primary boundary objects, secondary boundary objects are flexible and malleable in that they can be transformed and modified over time, although changes fundamentally impact actors' modes of acting and knowledge sharing (Nicolini, Mengis and Swan, 2012).

A key secondary boundary object example is the interdisciplinary collaborative process (framework main component 2, Figure 7.2) that guides, supports and mediates interdisciplinary team collaboration around primary boundary objects (particularly the project and app). The process provides a subsidiary role in guiding interdisciplinary teams through design, development and evaluation steps and activities that lead to the production of an app, and serves as a mediator for representing, preserving, transmitting and translating modes of action and knowledge exchange (Dörendahl, 2015). It also functions as a mediator in revealing divergent (or possibly conflicting) perspectives, interpretations and interests between heterogeneous team members, which in turn invites and fosters novel ideation and knowledge generation (Dörendahl, 2015; Filip, 2016). Within the process, various mediating artefacts (such as shared taxonomies, checklists and toolkits in *"Secondary Design [and] General Boundary Objects"*, Figure 7.8) are employed, created and used to coordinate modes of action (activities) and knowledge sharing between interdisciplinary collaborating team members.

***Tertiary Boundary Objects***

*Tertiary boundary objects* (right-positioned light blue shaded circle in Figure 7.8) are sociomaterial infrastructures and "mundane" artefacts that indirectly support and sustain collaboration (Nicolini, Mengis and Swan, 2012, p.49). Although Star (1999, p.377) refers to tertiary boundary objects as "boring things", collaborative teamwork is not possible without them (Nicolini, Mengis and Swan, 2012). Tertiary boundary objects are abstracted from direct motivation (primary) and direct representation (secondary) functions, and "transcend the more immediate necessities of productive prax[e]s" (Wartofsky, 1979, p.208; Bertelsen, 1998). They derive from social and sociomaterial human needs, and are adopted and utilised by interdisciplinary teams when carrying out "ordinary this-worldly" practices (Wartofsky, 1979, p.209). They generally remain in the background and are only called to the forefront when action and knowledge practices necessitate them (Nicolini, Mengis and Swan, 2012). When utilised, they become rooted and embedded in the interdisciplinary team's productive praxes, but do not depend on the praxes to exist as artefacts (Nicolini, Mengis and Swan, 2012). Ironically, the interdisciplinary collaborating team's process activities and knowledge sharing praxes become dependent on tertiary boundary objects to be actionised in a pragmatic reality. Moreover, despite their "mundane" sociomaterial infrastructure, they are able to indirectly influence a team's capability to engage in productive praxes and are able to mediate changes in members' imaginations, perceptions and conceptions, thereby mediating changes in modes of action and operation (Bertelsen, 1998; Nicolini, Mengis and Swan, 2012).

Examples of tertiary boundary objects include computers and laptops, mobile devices, CAD and app prototyping software, buildings, rooms (for meetings, workshops, et cetera), papers, paint, pens and colouring pencils, PowerPoint presentations, furniture and communication systems (such as e-mail) (illustrated in *"Tertiary Design [and] General Boundary Objects"*, Figure 7.8). All of these tertiary boundary objects indirectly support and sustain collaboration, yet without their sociomaterial infrastructure existence, collaboration would not be possible. They also indirectly influence practice. For instance, if a team has organised an app prototyping workshop to take place in a booked venue room on a specific date at a specific time, and the venue suddenly becomes unavailable, then the team's ability to run the workshop and engage in action and knowledge sharing praxes becomes disrupted. This disruption can negatively affect the team's project plans and activity deadlines.

#### 7.5.2.3.2 Two Types of Boundary Objects: Design and General

In Figure 7.8, primary, secondary and tertiary boundary objects are further classified into two types: (1) *design boundary objects*, and (2) *general boundary objects*. These two boundary object types represent sub-subclasses of the primary, secondary and tertiary categories (depicted by the upwards extending dark blue, sky blue and light blue inheritance arrows, respectively, Figure 7.8) and the boundary object superclass. This sub-subclass classification signifies multiple inheritance (Wilson, 1995); whereby the design and general boundary object types inherit the properties, roles and functionalities of both the three (primary, secondary and tertiary) category subclasses and the overarching boundary object superclass. In the proposed framework, design and general boundary objects are differentiated for two reasons: (1) design artefacts perform an integral role in mediating diverse design knowledge and heteropraxial design activities between multiple practice communities, and (2) design knowledge and activities are intrinsically embedded in the production of mHealth (physical activity) behaviour change intervention apps.

***Design Boundary Objects***

*Design boundary objects* (the three purple-outlined circles at the bottom left of the primary, secondary and tertiary circles in Figure 7.8) are design artefacts that enable, facilitate and drive the coordination and integration of heterogeneous design knowledge and heteropraxial design activities by mediating different design viewpoints and interpretations, supporting negotiation and conflict resolution engagements, and aiding the alignment of divergent interests to achieve shared understanding and common goals (Bertelsen, 1998; 2000; Bergman, Lyytinen and Mark, 2007). In mHealth (physical activity) behaviour change intervention app projects, the joint and collaborative use of design boundary objects in shared problem and solution boundary spaces largely ties together interdisciplinary team design knowledge and productive action (Bergman, Lyytinen and Mark, 2007).

Design boundary objects operate through functional design ecology (the processes and interactions regarding the goals and functions of feasible design solutions) and political design ecology (the institutional power structures and relational power dynamics surrounding design solutions and situations) (Bergman, Lyytinen and Mark, 2007). Their functional and political capabilities allows them to serve as central mediators of collaborative design teamwork and problem solving during the interdisciplinary process (Bergman, Lyytinen and Mark, 2007; Dupont, et al., 2012) and as motivational drivers of design innovation (Johnson, et al., 2017).

There exists a myriad of symbolic interactionist and sociomaterial interactions between team members and (primary, secondary and tertiary) design boundary objects at every stage of the interdisciplinary collaborative process, as objects assume and embody a multitude of diverse shapes, forms and functions, most of which are multidimensional, multi-faceted and multi-layered given the complexity and messiness of shared design problem and solution spaces (Bertelsen, 1998; 1999; 2000; Bergman, Lyytinen and Mark, 2007). The project, process and production of a product (consumer app) is heavily contingent on design boundary objects and their capacity to directly and indirectly support conceptual (intangible), communicative, coordinative, cooperative, collaborative and constructive (tangible) knowledge and practice sharing across heterogeneous community boundaries (Bertelsen, 1998; 2000).

mHealth (physical activity) behaviour change intervention app prototypes in various low-, medium- and high-fidelity shapes and forms are epitomes of design boundary objects (illustrated in *"Primary Design Boundary Objects"*, Figure 7.8). App prototypes mediate design knowledge and praxis throughout the project process by allowing interdisciplinary team members to communicate, visually describe and negotiate their different assumptions, perspectives, interpretations, ideas and suggestions around a tangible and material common point of reference, which facilitates the team's development of shared understandings and agreements about the app's final product design (Rhinow, Köppen and Meinenl, 2012; Winkler, Huber and Dibbern, 2014; Heiss, 2020). In other words, app prototypes provide interdisciplinary teams with a shared artefact that allows them to partake in iterative cycles of explicitly externalising, communicating and converging their different design perspectives and contributions through open engagement, perspective-making, perspective-taking, mental modelling and sensemaking practices (Rhinow, Köppen and Meinenl, 2012). These engagements also push interdisciplinary collaborating team members to continuously de-construct, re-construct, evolve and transform their design knowledge, and stretch their minds beyond the boundaries of their own practice communities, to enter in unfamiliar territory where innovative and enriched hybrid design solutions can emerge (Johnson, et al., 2017; Heiss, 2020).

Overall, design boundary objects – such as app prototypes – are indispensable to the production of mHealth (physical activity) behaviour change intervention apps, and the apps themselves emerge from the mHealth project and enacted interdisciplinary process as real world crystallised manifestations of commixed design knowledge and design praxes.

***General Boundary Objects***

*General boundary objects* (the three pink-outlined circles at the bottom right of the primary, secondary and tertiary circles in Figure 7.8) are artefacts that are employed, utilised and created by interdisciplinary team members when engaging in non-design related project, process and knowledge praxes, meaning that they refer to all of the other artefacts that meet the criteria for boundary objects, yet are not specifically design focused. They are nevertheless essential and important for the formation, management and sustainability of the mHealth intervention app project, collaborative process and interdisciplinary team. They serve an instrumental role as mediators and facilitators of knowledge and practice collaboration betwixt heterogeneous practice communities (Huvila, et al., 2016). In their absence, the project, process and team are likely to fail since they generally provide various forms of foundational guidance and organisational support for communicative, cooperative, coordinative and collaborative formalities and operations within the project boundary (Star, 2010). Key examples of general boundary objects are shared team, business and project documentation (illustrated in *"Secondary General Boundary Objects"*, Figure 7.8).

### 7.5.3 Supporting Artefacts

*"Supporting artefacts"* constitute the second aspect of the *"boundary objects and supporting artefacts"* component (Figure 7.8). *Supporting artefacts* are artefacts that guide, inform, support and facilitate interdisciplinary team members in carrying out heterogeneous knowledge sharing and heteropraxial activities during a mHealth intervention app project and process. Supporting artefacts are necessary and useful for achieving the project, team, process and product (app) goal and objective outcomes, and can be differentiated from boundary objects in terms of their properties, characteristics and nature qualities, as well as the roles and functionalities they assume when employed, adapted and utilised by interdisciplinary collaborating teams in pragmatic sociomaterial and symbolic interactionist situational settings. The critical theoretical analysis findings (Chapter 6) reveal that some supporting artefacts hold truth value (such as theories), while others provide utile value (such as frameworks, guidelines, standards, processes and methods) (Iivari, 2007; Hevner and Chatterjee, 2010). Supporting artefacts' local value derives from interdisciplinary team members' actions towards, around and with them in pragmatic enacted use and context within project boundaries (Wenger, 2010; Nicolini, Mengis and Swan, 2012).

#### 7.5.3.1 Supporting Artefacts: Properties, Characteristics and Nature

***Supporting Artefacts: Properties***

Foremost, supporting artefacts can be distinguished from boundary objects in that they do not meet the three core properties of boundary objects. In some cases, a supporting artefact may meet one or two core property criteria, but can never meet all three criteria – in which case their core structure would be altered, shifting them into assuming a boundary object status and role. Another key distinction is that supporting artefacts reside as global independent artefacts outside of the *"project boundary"* (framework supplementary component 1, Figure 7.2). Regardless of whether they are employed, referred to, adapted and utilised to suit the local project, team, process and product (app) contexts and situational settings, in order to serve particular purposes or achieve specific objectives, their global core properties and basic structure remains independent and stable. In other words, global artefacts are 'borrowed' and adapted to suit local contexts and settings, but their adapted use does not alter their global core structure, and when they are no longer in local use, their global existence and value does not cease or become obsolete (hence their independence and stability). Likewise, when mHealth intervention app projects, teams, processes and products (apps) terminate or discontinue, the global lifespans of supporting artefacts remain unaffected and continue to endure because they 'live' and exist independently outside of the project boundary.

For example, on a specific mHealth intervention app project, an interdisciplinary team may reference and use the WHO's (2010b; 2020c) *Global Recommendations on Physical Activity for Health* (illustrated in *"Supporting Guidelines, Standards and Codes of Practice"*, Figure 7.8) to inform the design, development and evaluation of a specific mHealth physical activity behaviour change intervention app. The team is essentially 'borrowing' guidelines that exist globally and 'live' independently outside of the local project boundary. The team may choose to apply a few select physical activity guidelines from the global document – for instance, to define a health behavioural goal that aims to encourage individuals to engage in 150-300 minutes of moderate-intensity activity per week (Chapter 3, Figure 3.3) – but this localised use does not alter the core structure or stability of the WHO's guidelines.

***Supporting Artefacts: Characteristics and Nature Qualities***

While supporting artefacts and boundary objects can be clearly differentiated in terms of core properties, they do share similar characteristics and nature qualities. In terms of characteristics,

supporting artefacts can exist in abstract and/or concrete forms; incorporate plurality and neutrality; often be contextualised to fit a project, team, process and product (app) context and situational setting; offer standardisation and/or flexibility; offer visualisation; be annotated; and need to be accessible, useful, stable and up-to-date for interdisciplinary collaborating teams to use within localised project boundaries. With regard to nature qualities, supporting artefacts can be blurry or ambiguous; transitional and dynamic (in terms of foreground and background, and knowledge capabilities); shift in status and role (in terms of contextual, actor-related and relational shifting); and are evolutionary over time.

#### 7.5.3.2 Supporting Artefacts: Three Categories

In Figure 7.8, supporting artefact are classified into three categories: (1) *supporting methods*; (2) *supporting guidelines, standards and codes of practice*; and (3) *other supporting artefacts and materials*. The category labels are informed by the critical analysis findings (Chapter 6). The three categories represent subclasses of the superclass, supporting artefacts, illustrated by the three green inheritance arrows extending upwards from the "methods", "guidelines, standards and codes of practice" and "other artefacts" categories into the overarching green shaded "supporting artefacts" subcomponent (Figure 7.8). Inheritance arrows are used in the same manner as discussed in Subsection 7.5.2.3.1, essentially indicating when "a concept… has two or more subtypes" (Wazlawick, 2014, p.138). The inherence arrows therefore convey the three categories of supporting artefacts (depicted with dark orange, light orange and yellow colour-outlined circles, respectively, Figure 7.8) as inheriting the properties, characteristics, nature qualities, roles and functionalities of supporting artefacts (as a superclass).

***Supporting Methods***

*Supporting methods* (the dark orange-outlined circle in Figure 7.8) are artefacts that provide team members with guidance and support for carrying out specific steps, activities and tasks during the interdisciplinary collaborative process, and are generally in the form of methodologies, processes and methods. When borrowing, adapting and applying a supporting method in a localised project context and situational setting, it can be used as a whole, or particular aspects of it can be electively selected, depending on the specific purpose and objective of its use in relation to a given step, activity or task. Notably, supporting methods are not primary drivers of the project's main interdisciplinary collaborative process (framework main component 2, Figure 7.2), instead they serve a secondary supplementary and auxiliary role in supporting collaborating team members to perform and complete smaller steps,

activities and tasks within the overall project process. Therefore, depending on the context, situational setting and objective, team members can employ, refer to, draw from, adapt and utilise more than one supporting method. The selection of a supporting method is at the discretion of the interdisciplinary collaborating team, and should appropriately fit the knowledge, expertise, skills and experience of the team, and be suitable for the intended context/situational setting and pre-determined objective.

Examples of supporting methods include: agile methodologies; mobile app development methodologies; alpha testing methods; beta testing methods; continuous improvement and continuous development (CI/CD) processes; development and operations (DevOps) methodologies and processes; RCT, MOST, SMART and TIPs processes and methods; and just-in-time adaptive intervention (JITAI) methods (illustrated by the various icons in *"Supporting Methods"* in Figure 7.8). All of these supporting methods can be employed, referred to, adapted and applied during specific steps, activities and tasks within the overall interdisciplinary collaborative design, development and evaluation process.

***Supporting Guidelines, Standards and Codes of Practice***

*Supporting guidelines, standards and codes of practice* (the light orange-outlined circle in Figure 7.8) are artefacts that provide interdisciplinary collaborating team members with guidance, support and measures for ensuring adherence to regulatory standards and quality specifications, and can be in the form of guidelines, recommendations, principles, legislature, regulations, rules, standards, codes of practice, codes of conduct, codes of ethics, procedures and policies. Supporting guidelines, standards and codes of practice, likewise with supporting methods, are borrowed from outside the project boundary and the team can refer to, use and apply them within the project boundary to help them carry out specific steps, activities and tasks, and achieve specific pre-determined objectives. They generally provide utile, rather than truth, value (Iivari, 2007; Hevner and Chatterjee, 2010). Similarly, depending on the artefact, the team may choose to refer to, apply and adhere to particular aspects of the artefact (such as applying a few select guidelines from the WHO's *Global Recommendations on Physical Activity for Health*), or may need to apply and adhere to all aspects of the artefact (such as the Android and Apple mobile app developer, security, privacy, intellectual property and human user interface standards and policies) (illustrated in *"Supporting Methods",* Figure 7.8).

Examples of other supporting guidelines, standards and codes of practice include: the British Standards Institution's *PAS 277:2015 Health and Wellness Apps – Quality Criteria Across the Life Cycle* as a code of practice; other physical activity, exercise, sport and training programmes and guidelines; and other guideline artefacts, for instance, reporting guidelines (such as CONSORT-EHEALTH) and ethical standards, policies, procedures and guidelines (illustrated by the various icons in *"Supporting Guidelines, Standards and Codes of Practice"* in Figure 7.8).

***Other Supporting Artefacts and Materials***

*Other supporting artefacts and materials* (the yellow-outlined circle in Figure 7.8) are other residual artefacts and materials that team members can review, refer to, employ, adapt, utilise and apply to carry out specific steps, activities and tasks during the interdisciplinary collaborative process; residual artefacts and materials that do not fall under the "supporting methods" or "supporting guidelines, standards and codes of practice" categories. Supporting artefacts and materials, likewise with the other two categories, are borrowed from outside the project boundary and are used by teams on a local level to carry out specific steps, activities and tasks, and achieve specific pre-determined objectives. Some supporting artefacts and materials provide truth value (such as theories, theoretical frameworks, models and empirical evidence) while others provide utile value (such as existing mHealth physical activity apps, checklists, publications, canvases, extant literature and creative tools) (Iivari, 2007; Hevner and Chatterjee, 2010). Furthermore, depending on the team members' knowledge, expertise, skills and experience, the activity/task objective, and the context/situational setting, it is at the discretion of the team to choose which supporting artefacts and materials they borrow, and they can be used as a whole, or particular aspects of them can be electively selected for use.

Examples of supporting artefacts and materials include: the *PRECEDE-PROCEED Framework and Model*; checklists; academic publications; report publications; canvases (such as *The Business Model Canvas*); extant literature; creative materials (such as notebooks, sticky notes, paper, colouring pencils, pens, paints, paint brushes); the *Framework for Physical Activity as a Complex and Multidimensional Behaviour* (Gabriel, Morrow and Woolsey, 2012); and existing commercial and research mHealth physical activity apps, such as *MyFitnessPal*, *Sweat*, *BetterMe*: *Weight Loss*, *8fit Workouts*, *Strava*, *Freeletics*, and *30 Day Fitness Challenge* (illustrated by the various icons in *"Other Supporting Artefacts and Materials"* in Figure 7.8).

Notably, it is acknowledged that the distinction between certain artefacts and materials, particularly stationery, may be initially blurry and ambiguous considering that these examples fall under both the *"Tertiary Design Boundary Objects"* and *"Other Supporting Artefact and Materials"* categories. However, to reiterate, the clear differentiation between such artefacts heavily relies on whether or not they meet the three core property criteria for boundary objects when used by a specific interdisciplinary team, within a particular project, process and product context and situational setting, because their value derives from practice enactment. Even Star (2010, p.613), the seminal author of boundary object theory, argues that objects, as simple stationery, can be boundary objects in "certain circumstances", depending on whether they cater for scale and scope and meet the three core boundary object properties.

### 7.5.4 Boundary Objects and Supporting Artefacts: Application

#### 7.5.4.1 Guideline Recommendations for Applying Boundary Objects and Supporting Artefacts

Considering that boundary objects and supporting artefacts constitute an indispensable and integral role in any given mHealth (physical activity) behaviour change intervention app project's design, development and evaluation process – from project inception as a proposal to the final published consumer app product – it is impossible for interdisciplinary collaborating teams to achieve the project and product (app) goal and objective outcomes without their presence and use. In other words, it is inevitable that interdisciplinary collaborating teams will employ, utilise and create a multitudinous range of diverse boundary objects and supporting artefacts at each step of any given mHealth intervention app project process and at every stage of a physical activity app's lifespan. Furthermore, considering the wide-ranging social, cultural, historical, environmental, and socioecological factors that influence and are influenced by the contextual and situational settings of any given mHealth intervention app project (discussed throughout Chapters 3 and 4), it is infeasible to state or predict all possible boundary objects and supporting artefacts that can be used when carrying out mHealth (physical activity) behaviour change intervention app projects. This infeasibility is evidenced by the myriad of boundary objects and supporting artefacts identified during the critical theoretical analysis (Chapter 6). Moreover, considering that it is impossible to state or predict all possible sociomaterial and relational interactionist contexts and situational settings in which boundary objects and supporting artefacts can be employed, utilised, adapted and created, and considering that the truth and utile value of objects and artefacts derives from their pragmatic symbolic interactionist and sociomaterial use in practice, it is unreasonable to attempt to

provide ideal or absolute generalised guideline recommendations that can be used for guiding perfect application in all mHealth intervention app projects.

In light of these considerations and caveats, the guideline recommendations for applying the proposed framework's boundary objects and supporting artefacts component are not rigidly prescriptive or standardised, but instead are suggestive, thereby open for review, deliberation, discussion and adaptation by interdisciplinary collaborating team members within the localised context of their particular mHealth intervention app project boundary. As outlined in Table 7.7, the three main guideline recommendations for application entail: (1) *understanding boundary objects and supporting artefacts*; (2) *reviewing and understanding the mHealth project and domain*; and (3) *continuously track, record and update boundary objects and supporting artefacts documentation*. Important to reiterate is that these guideline recommendations (serving as a template) are suggestive, and considering they may demand significant time and resources to execute fully in practice, their real world application may not always be feasible, and hence teams may choose to apply certain guidelines more lightly or heavily; for example, only documenting several key, and not all, boundary objects during the project process.

*Table 7. 7: Guideline Recommendations for Applying Boundary Objects and Supporting Artefacts [Source: Researcher's own construction]*

| **Guideline Recommendation Number and Title** *[Stage of Project Life Cycle]* | |
|---|---|
| **Guideline No.** | **Description of Guideline Recommendation** |
| **Guideline 1: Understanding Boundary Objects and Supporting Artefacts** *[Preliminary – Prior to Project Initiation]* | |
| **G.1** | 1.1. Understand what boundary objects and supporting artefacts are in terms of their definitions.<br>1.2. Understand the properties, characteristics and nature qualities of boundary objects and supporting artefacts.<br>1.3. Be able to distinguish between boundary objects and supporting artefacts.<br>1.4. Understand the three (primary, secondary and tertiary) categories and two (design and general) types of boundary objects.<br>1.5. Understand the three categories of supporting artefacts (supporting methods; supporting guidelines, standards and codes of practice; and other supporting artefacts and materials).<br>1.6. Be able to distinguish between the respective categories and types of artefacts.<br>1.7. Be able to identify and determine categories and types for real world objects and artefacts.<br>1.8. Be able to record, report and document on boundary objects and supporting artefacts. |
| **Guideline 2: Reviewing and Understanding the mHealth Project and Domain** *[Project Launch and Initiation]* | |
| **G.2** | 2.1. Based on interdisciplinary team members' knowledge, expertise, skills and past experiences and a domain study review of other existing mHealth intervention app projects with similar health promotion and health behavioural outcome objectives and similar digital mobile app design objectives, identify appropriate boundary objects in terms of:<br>2.1.1. The shared mHealth intervention app project<br>2.1.2. The interdisciplinary collaborating team *<br>2.1.3. The shared interdisciplinary collaborative process **<br>2.1.4. The intended mHealth behaviour change intervention consumer app product ~<br>2.1.5. The management of boundary objects ⁰ |

| | |
|---|---|
| | 2.2. Based on interdisciplinary team members' knowledge, expertise, skills and past experiences and a domain study review of other existing mHealth intervention app projects with similar health promotion and health behavioural outcome objectives and similar digital mobile app design objectives, identify appropriate supporting artefacts in terms of:<br>2.2.1. The shared mHealth intervention app project<br>2.2.2. The interdisciplinary collaborating team *<br>2.2.3. The shared interdisciplinary collaborative process **<br>2.2.4. The intended mHealth behaviour change intervention consumer app product ~<br>2.2.5. The management of supporting artefacts $^{oo}$ |
| **Guideline 3: Continuously Track, Record and Update Boundary Objects and Supporting Artefacts Documentation** *[All Project Stages]* | |
| **G.3** | 3.1. Track, record and document all boundary objects that are employed, adapted, utilised and created by the interdisciplinary collaborating team throughout the duration of the mHealth intervention app project's lifespan. Continuously update boundary object documentation by recording all new additions and modifications of boundary objects in terms of:<br>3.1.1. The shared mHealth intervention app project<br>3.1.2. The interdisciplinary collaborating team *<br>3.1.3. The shared interdisciplinary collaborating process **<br>3.1.4. The intended mHealth behaviour change intervention consumer app product ~<br>3.1.5. The management of boundary objects $^{o}$<br>3.2. Track, record and document all supporting artefacts that are borrowed, employed, referred to, drawn from, utilised, adapted and discarded by the interdisciplinary collaborating team throughout the duration of the mHealth intervention app project's lifespan. Continuously update supporting artefact documentation by recording all new additions and modifications of supporting artefacts in terms of:<br>3.2.1. The shared mHealth intervention app project<br>3.2.2. The interdisciplinary collaborating team *<br>3.2.3. The shared interdisciplinary collaborative process **<br>3.2.4. The intended mHealth behaviour change intervention consumer app product ~<br>3.2.5. The management of supporting artefacts $^{oo}$ |
| **Key Identifiers – Examples of Boundary Objects and Supporting Artefacts:**<br>* Figure 7.3; Figure 7.4; Table 7.2; Appendix J.1; Appendix J.2; and Appendix J.3.<br>** Table 7.1; Figure 7.5; Figure 7.6;Table 7.3; Appendix K.3; and *Guideline Recommendations for Applying the Interdisciplinary Collaborative Process*.<br>~ Literature review findings relevant to mHealth physical activity behaviour change intervention apps (Chapters 3 and 4).<br>$^{o}$ Figure 7.7; Figure 7.8; Table 7.4; Table 7.5; Table 7.6; and Table 7.7.<br>$^{oo}$ Figure 7.7; Figure 7.8; and Table 7.7. | |

### 7.5.5 Boundary Objects and Supporting Artefacts: Summary and Boundary Objects

Section 7.5 has provided a clipping (Figure 7.7) and detailed perspective (Figure 7.8) of the proposed Interdisciplinary mHealth App Design Framework's third main *"boundary objects and supporting artefacts"* component. Corresponding to Figure 7.8, Table 7.4, Table 7.5 and Table 7.6 have provided detailed descriptions and examples of the three *"core properties"*, sixteen *"characteristics"* and several *"nature qualities"* of boundary objects. After which, the three *"primary, secondary and tertiary"* categories and two *"design and general"* types of boundary objects have been described with examples. Furthermore, *"guideline recommendations"* have been proposed for applying the framework's boundary objects and supporting artefacts component in practice (Table 7.7).

Overall, these six *"boundary objects and supporting artefacts"* component contributions can be employed by mHealth intervention app project teams to serve as boundary objects and common points of reference points that can be flexibly adapted and particularised to suit various mHealth project, team, process and product (app) contexts (Star and Griesemer, 1989; Carlile, 2004; Star, 2010). In drawing to a close, the indispensable, integral and embedded role of boundary objects and supporting artefacts in carrying out successful mHealth intervention app projects and producing innovative and effective mHealth (physical activity) behaviour change intervention consumer app products has been underscored and emphasised. On a final note, the discussions in Section 7.5 have further uncovered and demonstrated the complex and intricate pragmatic and sociomaterial and relationship entanglements between the proposed framework's four main *"actors"*, *"interdisciplinary collaborative process"*, *"knowledge"* and *"boundary objects and supporting artefacts"* components, as well as the two supplementary *"project boundary"* and *"outcomes"* components (Figure 7.2).

## 7.6 Knowledge

### 7.6.1 Knowledge: A Detailed Perspective

Figure 7.9 provides a clipping of the "*knowledge*" component from Figure 7.2, pertaining to the cognitive, conceptual and communicative aspect of the proposed framework that supports perspective sharing, sensemaking, learning and understanding between actors. In honing in on the "knowledge" component of Figure 7.2, Figure 7.10 presents a more detailed perspective of the "*knowledge boundaries*" that arise between interdisciplinary collaborating team members, and the "*knowledge processes*", "*communication processes*", *"knowledge boundary aims"*, "*shared understanding*" and "*boundary objects (knowledge artefacts)*" that assist teams in overcoming these boundaries. The knowledge artefact example illustrations in Figure 7.10 are not exhaustive or strictly prescriptive (object and artefact icons detailed in Appendix L.1).

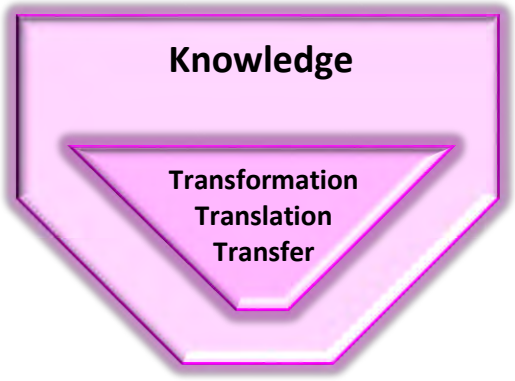



*Figure 7. 9: "Knowledge": Main Component 4 of the Proposed Framework [Source: Researcher's own construction]*

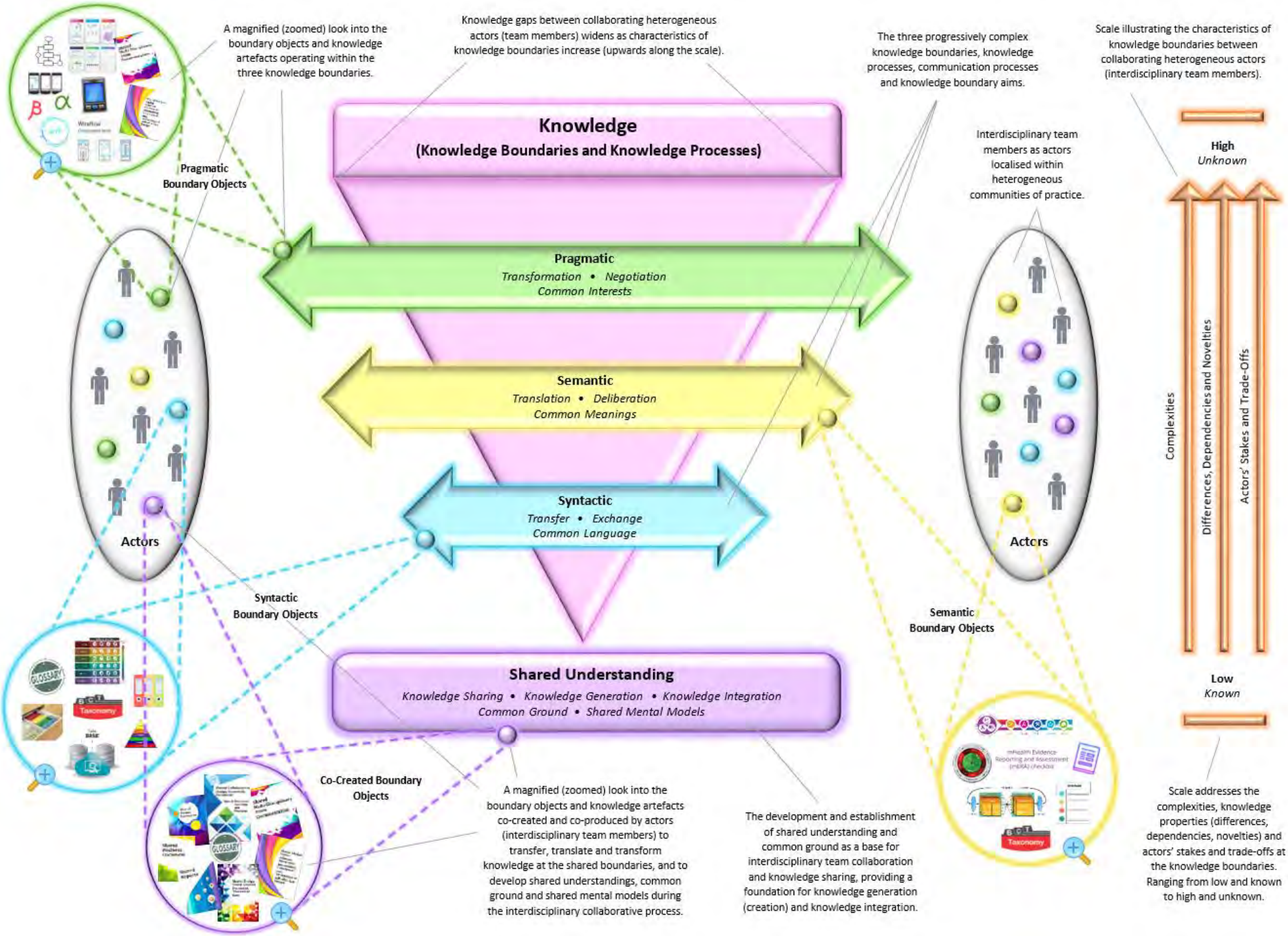



*Figure 7. 10: "Knowledge" Detailed Perspective: Main Component 4 of the Proposed Framework*
*[Source: Researcher's own construction, object and artefact example icons clearly illustrated and identified in Appendix L.1]*

In Figure 7.10, the elements constituting the detailed perspective of the framework's *"knowledge"* component are informed by knowledge boundary theory (Chapter 5, Section 5.3.3), the critical theoretical analysis findings (Chapter 6, Section 6.5.6), relevant doctoral dissertations (such as Bertelsen, 1998; Mengis, 2007; Melville-Richards, 2015; Filip, 2016; Stange, 2017; Caccamo, 2020), books (such as Tell, et al., 2017), and other literature publications (such as Gomes, Tzortzopoulos and Kagioglou, 2016; Cash, Dekoninck and Ahmed-Kristensen, 2017; Gomes and Tzortzopoulos, 2018; Damen, et al., 2020).

***Understanding the Nature and Perspective of Knowledge in the Proposed Framework***

*Knowledge* is complexly and intricately interwoven as an essential and binding element for enabling and facilitating interdisciplinary team communication, coordination, cooperation, collaboration, cohesion, negotiation and joint decision-making (Tell, et al., 2017; Gerdes, et al., 2020). While there remains no universally accepted and consensus definition for knowledge, it is often described as a theoretical and/or practical understanding of information, practices, processes, situations and interactions that is acquired through educational and lived experiences by discovering, perceiving, conceiving, cognising, sensemaking and learning (Filip, 2016).

Knowledge can be *tacit knowledge* ("knowing how") or *explicit knowledge* ("knowing about") (Uusitalo, 2015; Tell, et al., 2017, p.211). *Tacit knowledge* is subjective and internalised, and is gained through experience and practice in context, is challenging to explicitly articulate, and is difficult to translate and share (Tell, et al., 2017). For example, a knowledge broker (such as a team leader, Figure 7.4) with previous experience in managing interdisciplinary mHealth intervention app projects will possess tacit knowledge in "knowing how" manage interdisciplinary teams' negotiations and heteropraxial activities. *Explicit knowledge*, in comparison, can be readily articulated, codified, stored, accessed and transferred through formal and systematic language and other media (such as documentation) (Tell, et al., 2017). For example, the *Interdisciplinary Team Member and Perspectives Template* (Appendix J.2), which provides documented information for team members to cognise and "know about" each other's practice communities and contributions to the project, team, process and product.

Sharing explicit knowledge is a relatively straightforward endeavour, whereas articulating and sharing implicit knowledge is a more complicated, iterative and challenging task that requires substantial effort, willingness, commitment and time investment (Stange, 2017; Rushmer, et

al., 2019). Implicit knowledge is "sticky" to context and disciplines of specialisation, making it difficult to transmit across disciplinary boundaries from one practice community to another (Tell, et al., 2017, p.48). Yet, for interdisciplinary teams to collaborate effectively and achieve their shared mHealth intervention app project outcomes, it becomes necessary that efforts be put towards overcoming knowledge boundaries, developing shared understanding, and making use of (and creating) knowledge artefacts that enable, support, facilitate and mediate the "stickiness" of knowledge sharing and knowledge building (Tell, et al., 2017, p.139).

Knowledge sharing and building can be viewed from different perspectives. The base diagram in Figure 7.9 and Figure 7.10 draws from and adapts Carlile's (2004) framework, which adopts a pragmatic perspective that considers the practical challenges and resistances faced in balancing knowledge sharing and knowledge building practices, and argues for knowledge as a source of product innovation (such as innovative mHealth intervention app design solutions). In considering the criticisms framed against a purely pragmatic perspective (Kosonen, 2015; Uusitalo, 2015) and this research project's amalgamated pragmatic sociomaterial and symbolic interactionist perspective, two more complementary perspectives are incorporated in the proposed framework's knowledge component, namely a processual and dynamic perspective (Rakevicius, 2016) and a boundary object relational perspective (Dirckinck-Holmfeld, 2006). These perspectives view knowledge sharing and knowledge building as a collective (team) process of developing structures and capabilities for knowledge transformation (Rakevicius, 2016) and as a collaborative "interdisciplinary learning experience" that uses boundary objects as dynamic resources in relation to various context situations and project objectives (Dirckinck-Holmfeld, 2006; Uusitalo, 2015, p.198), respectively. While all four perspectives inform the view of knowledge in Figure 7.10, the pragmatic view of knowledge remains foundational.

### 7.6.2 Knowledge in Interdisciplinary Collaborating Team Projects

Knowledge sharing and knowledge building is indispensable and integral to the interdisciplinary team collaboration process, is deeply embedded and interwoven in mHealth intervention app project process activities, and becomes intricately ingrained and crystallised in the final product (physical activity app) output (Tell, et al., 2017; Gerdes, et al., 2020). The key challenge with knowledge in interdisciplinary collaborative project teamwork, however, is that it is "localised, embedded and invested in practice" (Carlile, 2002, p.442), which makes communication, coordination, cooperation and collaboration between heterogeneous actors,

and the accommodating and respecting of different knowledge perspectives and contributions, especially difficult in a pragmatic reality (Howard-Grenville and Carlile, 2006).

In order to share, transform, integrate and generate new knowledge, develop shared understandings, traverse knowledge boundaries, and co-produce hybrid innovative mHealth (physical activity) behaviour change intervention apps, interdisciplinary team members need to externalise their "deep knowledge" in a manner that actors from diverse practice communities can comprehend and understand (Majchrzak, More and Faraj, 2012, p.953; Uusitalo, 2015; Salwen-Deremer, et al., 2020). Knowledge therefore, ironically, becomes both a source and barrier to interdisciplinary team collaboration on mHealth intervention app projects, and paradoxically, the knowledge boundaries that arise betwixt heterogeneous communities become both a necessity and critical challenge that needs to be addressed and overcome for project success.

#### 7.6.2.1 Knowledge in Interdisciplinary Collaborating Team Projects: Knowledge Boundaries and Knowledge Processes

In Figure 7.10, the pink inverted equilibrium triangle and the three bidirectional arrows are based on Carlile's (2004) conceptual integrative framework for knowledge management. It portrays the three progressively complex *knowledge boundaries (syntactic, semantic and pragmatic)* and three progressively complex *knowledge processes (transfer, translation and transformation)* that arise between interdisciplinary collaborating team members stemming from heterogeneous practice communities (positioned on either side of the inverted triangle, Figure 7.10). In Figure 7.10, the pink colour corresponds to the proposed framework's main *"knowledge"* component (Figure 7.2), but the three green, yellow and blue bidirectional arrows do not correspond to the framework's main *"actor"*, *"project boundary"* or *"boundary object and supporting artefact"* components. Instead, in the context of Figure 7.10, the green, yellow and blue colours simply distinguish the three knowledge boundaries and knowledge processes.

On the right-hand side of Figure 7.10, the three upward-pointing orange arrows (positioned between two orange horizontal end containers) conveys an ascending scale, representing the different characteristics that exist at the knowledge boundaries between actors, ranging from "*low*" to "*high*" complexity and from what is "*known*" to "*unknown*" (Carlile, 2002; 2004). Each arrow corresponds to a different element of knowledge, which helps distinguish what kinds of resources and efforts are required by interdisciplinary collaborating team members to effectively overcome knowledge boundaries (Carlile, 2002; 2004). The left arrow (Figure 7.10)

represents increasingly complexities (from low to high) that are associated with the three knowledge boundaries and knowledge processes. The middle arrow (Figure 7.10) portrays the characteristics of three relational knowledge properties (differences, dependencies and novelties). The right arrow (Figure 7.10) conveys the increase in actors' stakes and trade-offs as knowledge boundary complexities and knowledge properties progressively increase.

The core theory underpinning the three relational knowledge properties and the three progressively complex knowledge boundaries and knowledge processes was discussed in detail in Chapter 5 (Section 5.3.3). For purposes of length, only brief descriptions highlighting key points are reiterated here in relation to the framework's *"knowledge"* component.

***Knowledge Properties***

The three knowledge properties – *difference, dependence and novelty* – clarify an understanding of the challenges and consequences that arise at a given boundary, and inform how knowledge can be better managed, traversed and integrated across the boundaries of collaborating practice communities (Carlile and Rebentisch, 2003; Carlile, 2004).

A *difference* in knowledge can be a difference in the type of community/specialised knowledge, or a difference in the volume of knowledge accumulated. Knowledge differences are essential for innovative hybrid design solutions to be developed, and are apparent through heterogeneous team members' different worldview perspectives, language, interpretations, levels of expertise, frameworks, approaches, interests and incentives (Carlile, 2004). The critical theoretical analysis findings revealed key differences in terminological interpretation of meaning due to interpretive flexibility. Examples include "usability", "adherence", "user experience", "engagement", "persuasiveness" and more (Chapter 6 and Appendix I).

A *dependency* in knowledge concerns the interrelationships and consequential links between interdisciplinary team members' knowledge, activities, tasks, goals and objectives, which are often path-dependent. Since team members tend to rely heavily on each other's specialised knowledge and skilled praxes, they need to be cognisant of the consequential impacts of their own knowledge, activities, tasks, goals and objectives on other team members (Carlile, 2004). A *novelty* in knowledge arises when new circumstances arise at a given boundary between interdisciplinary collaborating team members, such as the introduction of new actors, new knowledge, new mobile technology advancements, new specialised knowledge, new approaches, frameworks and methods, new informatic and work requirements, and new

consumer app product requirements; all of which indirectly and directly affect knowledge sharing and the development of shared understandings on mHealth intervention app projects. Examples of new methods published in recent years (from the critical analysis findings, Chapter 6 and Appendix I) include CEEBIT; MOST; SMART; TIPS; ABACUS; MARS; uMARS; APEASE; and the Health-ITUEM.

In Figure 7.10, the three knowledge properties on the upward-pointing orange arrow (ascending scale) complements and parallels the pink inverted equilibrium triangle. The inverted triangle conveys the movement (progression or regression) of the three knowledge properties as they increase and decrease in scale upwards and downwards along the complex knowledge boundaries and processes (Carlile, 2002; 2004). From the bottom tip of the inverted triangle, the two diverging sides represent a form of "boundary as a vector" between a minimum of two heterogeneous team members (positioned on either side of the vector) (Carlile, 2004, p.557). At the bottom tip of the inverted triangle and at the bottom end of the orange scale, complexities faced are generally *"low"* (Stange, 2017, p.38) and differences and dependencies are generally *"known"* (Carlile, 2004, p.557). However, as novelties increase and as differences and dependencies become more challenging and consequential, the vector diverges and spreads and the (knowledge boundary) gap widens, thus scaling the increasing complexity and amount of resources and effort required to manage the knowledge boundary and bridge the gap between interdisciplinary team members (Carlile, 2004; Stange, 2017). The introduction of increasingly more new circumstances causes a progressive movement upwards along the two diverging sides of the inverted triangle, eventually reaching the top end of the pink inverted triangle and the top end of the orange scale, where complexities faced are generally *"high"* (Stange, 2017, p.38) and differences and dependencies are generally *"unknown"* (Carlile, 2004, p.557). Therefore, depending on the scale of knowledge properties and the degree of complexities faced by an interdisciplinary collaborating team on any given mHealth (physical activity) behaviour change intervention app project, different knowledge boundaries (at *syntactic*, *semantic* and *pragmatic* levels) arise, requiring different boundary capabilities to overcome.

***Knowledge Boundaries***

At the *syntactic knowledge boundary* (bottom blue bidirectional arrow, Figure 7.10), differences and dependencies are relatively known, and the main boundary challenge concerns differences in language and vocabulary betwixt heterogeneous team members (Carlile, 2004). Knowledge processes involve information processing and the *transfer* of knowledge across

diverse practice community boundaries (Carlile, 2004) and communication processes focus on the *exchange* of knowledge (Stange, 2017). Overcoming differences in language and vocabulary, and creating shared understandings, requires a *common language* be developed (also referred to as a shared language, shared lexicon or shared repertoire) that adequately supports interdisciplinary collaborating team members' communications and helps resolve language and information processing problems (Carlile, 2004; Liu, et al., 2019).

At the *semantic knowledge boundary* (middle yellow bidirectional arrow, Figure 7.10), differences and dependencies are relatively unclear and somewhat unknown, and the main challenge concerns differences in meaning and interpretation betwixt heterogeneous team members, resulting in a loss of shared understanding (Carlile, 2004). Knowledge processes involve the *translation* of knowledge across diverse practice community boundaries (Carlile, 2004) and communication processes focus on the *deliberation* of knowledge (Stange, 2017). Reconciling discrepancies in meaning and interpretation, and creating shared understandings, requires the development of *common meanings* (shared meanings) that sufficiently support interdisciplinary collaborating team members in learning through articulating their different thought worlds and making tacit knowledge explicit (Carlile, 2004; Abraham, 2015; Melville-Richards, 2015; Gomes, Tzortzopoulos and Kagioglou, 2016).

At the *pragmatic knowledge boundary* (top green bidirectional arrow, Figure 7.10), differences and dependencies are largely unknown, and the main challenge concerns differences in (or conflicts of) interests betwixt heterogeneous team members, resulting in a further loss and fragmentation of shared understanding (Carlile, 2004; Mengis, 2007; Abraham, 2015; Melville-Richards, 2015; Gomes, Tzortzopoulos and Kagioglou, 2016). The pragmatic knowledge boundary is the most complex and laborious to overcome given that it introduces challenges regarding team members' political resistance, their perceptions of costs, abandonment, trade-offs, and viewing their knowledge to be "at stake" (Carlile, 2002, p.445). Knowledge processes involve the *transformation* of knowledge across diverse practice community boundaries (Carlile, 2004) and communication processes focus on the *negotiation* of knowledge (Stange, 2017). Reconciling political differences in interests, and creating shared goals and incentives, requires the development of *common interests* (shared interests) that adequately support interdisciplinary team members in generating new knowledge and creating innovative mHealth app design solutions (Carlile, 2002; 2004; Kosonen, 2015; Rakevicius, 2016; Stange, 2017; Liu, et al., 2019; Caccamo, 2020).

In Figure 7.10, although the boundary lines drawn are solid lines, knowledge boundary lines in real world practice are not fixed or hard-lined, but instead are generally fluid, indeterminate, dynamic, implicit and unspoken in nature (Star and Griesemer, 1989; Wenger, 2010). In addition, the three knowledge boundaries are not rigidly hierarchical considering that knowledge essentially flows up and down all three knowledge boundaries (Carlile, 2002; 2004). Although, the knowledge boundaries do build upon each other, for example, in order to share knowledge on a pragmatic level, an interdisciplinary collaborating team would need to have first developed sufficient syntactic and semantic knowledge (Carlile, 2004). Notably though, considering that knowledge is constantly changing and evolving over time, the syntactic and semantic knowledge developed by an interdisciplinary collaborating team does not need to be complete or absolute to adequately support pragmatic knowledge sharing practices (Carlile, 2002). On a final note, the political nature of pragmatic knowledge also corresponds to the third right orange ascending arrow (Figure 7.10), which illustrates how increases in differences, dependencies and novelties are associated with increases in actors' *"stakes"* and *"trade-offs"* at the shared boundary between heterogeneous collaborating team members in mHealth (physical activity) behaviour change intervention app projects.

#### 7.6.2.2 Knowledge in Interdisciplinary Collaborating Team Projects: An Elaboration on Actors

The actors depicted on the two sides of the knowledge boundaries in Figure 7.10 represent the *"actors"* discussed in the proposed framework's first main component (Section 7.3, illustrated in Figure 7.4). Noticeably, the actor icons in Figure 7.10 are grey in colour, whereas the various interdisciplinary collaborating team members (communities of practice) in Figure 7.4 are multi-coloured. The change from multiple colours to one neutral grey colour palette is intentional because Figure 7.10 is a simplification of the *"interdisciplinary team members"* within the *"project boundary"* (similar to the *"actors"* simplification in Figure 7.2). The main purpose of Figure 7.10 is to describe the *"knowledge"* component and illustrate how increases in complexities and knowledge properties drives the vector to diverge and knowledge boundary gaps to widen between (supposedly two) actors or communities of practice on either side of the inverted triangle. In real world practice, diverging knowledge boundary gaps arise between multiple actors or communities of practice, which would be overcrowded if illustrated in Figure 7.10, and hence the actors were neutralised and simplified. Figure 7.11 therefore provides a diagrammatic representation of multiple knowledge properties, knowledge boundaries and knowledge processes between all interdisciplinary team members (communities of practice).

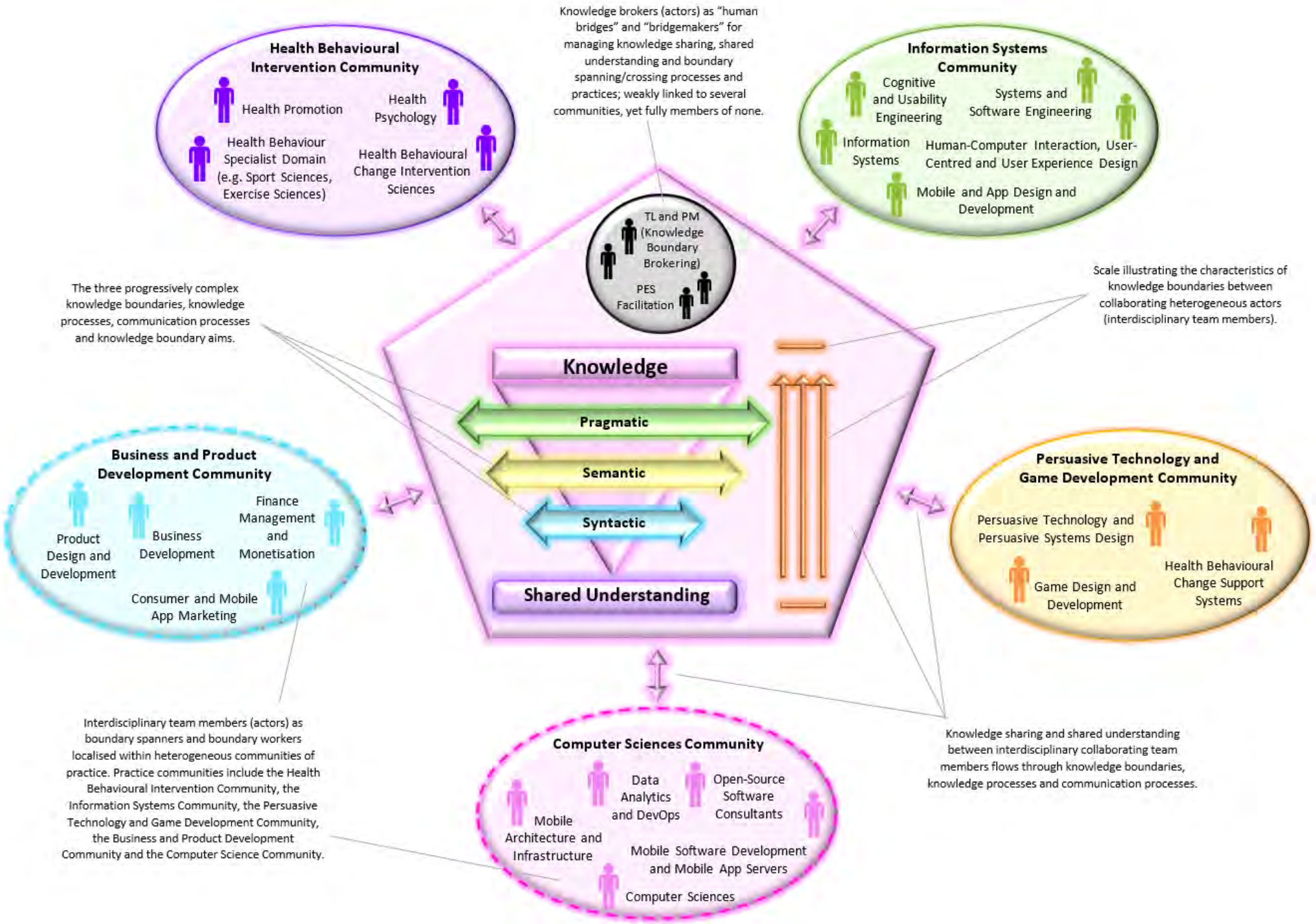



*Figure 7. 11: Knowledge Properties, Boundaries and Processes Between All of the Interdisciplinary Collaborating Team Members and Communities of Practice [Source: Researcher's own construction]*

In Figure 7.11, the general interdisciplinary team members localised within the five (purple, green, orange, light blue and pink) heterogeneous communities of practice operate as *"boundary spanners"* or *"boundary workers"* (Levina and Vaast, 2005; Akkerman and Bakker, 2011) and the black icon actors positioned within the pink knowledge pentagon operate as *"knowledge brokers"* of the whole mHealth (physical activity) intervention app project (Meyer, 2010; Rashmer, et al., 2019). Knowledge sharing and knowledge building essentially flows through all five of the pink shaded bidirectional arrows and across all of the knowledge boundaries. Notably, the number of boundary spanner/worker and knowledge broker actor icons in Figure 7.11 is not strictly prescriptive; they simply provide illustrative examples. Detailed descriptions of boundary spanning/crossing can be referred to in the discussions under the framework's first *"actors"* component (Subsection 7.3.1.1) and the proposed tri-composite theoretical framework (Chapter 5). Further details pertaining to knowledge brokers specifically (as initially stipulated in Subsection 7.3.1.1) requires an elaborated discussion.

***Knowledge Brokers***

The knowledge brokers are the glue that holds the general interdisciplinary collaborating team members (boundary spanners/workers), the process, and the overall mHealth intervention app project together. Positioned within the pink knowledge pentagon (Figure 7.11), they are the "human bridges" (Ganter, 2011, p.7) and "bridgemakers" (Filip, 2016, p.85) that are "weakly linked to several communities of practice at once [yet are] full members of none" (Rosenkranz, Vranešić and Holten, 2014, p.310). As depicted in Figure 7.11, the project's knowledge sharing and building practices are managed, facilitated, coordinated and mediated by and through them (Meyer, 2010; Filip, 2016). In mHealth intervention app projects, they generally assume roles as team leaders and project managers (two top-left TL and PM black actor icons) and as primary empirical study facilitators (two bottom-right PES black actor icons).

Although both roles engage in knowledge brokering activities, their team positioning/statuses, powers of influence, rights, responsibilities and decision-making authority differs. Team leaders and project managers hold primary chief reign and power over the team, project, process and product, while the primary empirical study facilitators exercise secondary reign and facilitation power when conducting and coordinating primary empirical studies at particular stages of the mHealth project and process. Regardless of reign positioning, both knowledge broker roles ought to remain neutral and impartial to any specific practice community, and ought to operate from an objective mediation standpoint when mediating

knowledge, communication and activity processes between collaborating team members (or communities) (Pawlowski and Robey, 2004; Elueze, 2015).

Knowledge brokers function as "intermediaries" (Olejniczak, 2017, p.554) and "facilitators" (Elueze, 2015, p.175), and can adequately speak the languages of all participating team members (or communities) in order to establish connections and links between them, engage in "import-export" knowledge practices, and bridge the knowledge gaps that arise at the three knowledge boundaries (Wenger, 1998, p.109; Rushmer, et al., 2019). They are also responsible for building bridges with actors outside of the *"interdisciplinary collaborating team"*, that is, with *"third party stakeholders"* and *"end users"* (*"actors"* component, Figure 7.4). In addition, they are often responsible for designing boundary spanning/crossing work processes and facilitating boundary spanners' interactions and practices, sometimes initiating interactions between other actors and other times directly partaking in interactions (Meyer, 2010; Filip, 2016). Furthermore, they hold sufficient knowledge about each community to be able to facilitate and mediate knowledge sharing, knowledge integration and knowledge generation, and to enable and support the development of shared understandings betwixt heterogeneous boundary spanners, which is fundamental to the success of interdisciplinary mHealth (physical activity) app projects and collaborating teams (Mengis, 2007; Melville-Richards, 2015; Tell, et al., 2017; Gomes and Tzortzopoulos, 2018; Damen, et al., 2020).

Knowledge brokers also "serve as windows into the relationship between learning and innovation" and are particularly involved with, and responsible for, knowledge negotiation, conflict resolution and decision-making practices (Meyer, 2010; Filip, 2016, p.85). They often pursue learning in new domains, are continuously learning and employing new knowledge brokering strategies to manage their knowledge broker identities, and are important drivers of innovation in interdisciplinary collaboration projects (Star and Griesemer, 1989; Meyer, 2010; Uusitalo, 2015; Filip, 2016). Moreover, they are responsible for mediating and challenging the worldview assumptions, perspectives and political resistance expressed by boundary spanners (Pawlowski and Robey, 2004), managing the political power dynamics within interdisciplinary collaborating teams, and engaging in political manoeuvring encapsulated in knowledge brokering and spanning practices (Rosenkranz, Vranešić and Holten, 2014).

Overall, knowledge brokers require extensive knowledge and a broad range of competencies and skills associated with negotiation, diplomacy, flexibility, conflict resolution, decision-making and interpersonal skills such as trust, active listening and empathy (Williams, 2012;

Kosonen, 2015). Knowledge brokering is an ongoing task that is fundamentally essential to the success of any mHealth (physical activity) intervention app project, team, process and product, and requires substantial effort, time and resources throughout the duration of the project's lifespan. Notably, given their significant, weighty and pressurised role, knowledge brokers often experience personal costs pertaining to their health and wellbeing due to the high and common risks resulting from work overload, excessive stress and burn out (Long, Cunningham and Braithwaite, 2013). Another concern, which can produce challenges and at times lead to interdisciplinary collaborative team, project, process and product failure, arises if knowledge brokers either lack the expertise required of their role or inadvertently function as bottlenecks, in which case they unintentionally withhold, distort, miscommunicate or mistranslate information and knowledge between the heterogeneous actors and communities of practice they manage (Long, Cunningham and Braithwaite, 2013).

### 7.6.3 Shared Understanding

*Shared understanding* (illustrated by the purple rectangle in Figure 7.10 and Figure 7.11) describes the collaborative and dynamic ability and effort of interdisciplinary team members to conceive and coordinate practices towards common (shared) goals or objectives ("meaning in use", pragmatic perspective), based on diverse knowledge, perspectives and interests, through the use of boundary objects (Bittner and Leimeister, 2013; Gomes and Tzortzopoulos, 2018, p.475; Kanwal, et al., 2019). Shared understanding aims to align and integrate multiple mental models, perspectives, beliefs, assumptions, interests, goals and objectives between heterogeneous actors (Cash, Dekoninck and Ahmed-Kristensen, 2017). Shared understanding relates similarities between individual actors' perspectives and perceptions about how a design topics are conceptualised, what the content of situational settings are, or how transactive memory systems work, as a process to conceiving common (design) solutions (Gomes and Tzortzopoulos, 2018). The transactive memory system consists of the knowledge stored in individual actors' memory systems combined with metamemory, which contains information regarding the different specialisation/community knowledge processed by other actors within the team, creating a form of shared awareness between interdisciplinary team members (Wegner, 1986; Gomes and Tzortzopoulos, 2018).

Developing and maintaining shared understanding is crucial for interdisciplinary collaborative team and project success because it provides a foundational base for enabling and supporting communication, coordination, cooperation, collaboration, negotiation and knowledge sharing

practices between heterogeneous team members (and communities of practice) (Abraham, 2015; Gomes, Tzortzopoulos and Kagioglou, 2016; Cash, Dekoninck and Ahmed-Kristensen, 2017). Bittner and Leimeister (2013, p.134) emphasise that "building a shared understanding early on [in a project] is critical". A break down or deficit of shared understanding between interdisciplinary collaborating team members produces fragmentations in their perspectives, perceptions and mental models, which leads to hindrances and failures in knowledge sharing, knowledge brokering and boundary spanning/crossing practices, as well as obstructions in collaborative design, development and evaluation process activities, making joint problem solving and shared goal/objective attainment impractical and infeasible (Engeström, Engeström and Kärkkäinen, 1995; Bittner and Leimeister, 2013; Uusitalo, 2015; Gomes and Tzortzopoulos, 2018).

"[O]nly after shared understanding has been established at a given knowledge boundary, can knowledge be shared via processes of knowledge transfer… knowledge translation [and] knowledge transformation", emphasises Abraham (2015, p.12). This notion is echoed by Rosenkranz, Vranešić and Holten (2014, p.308) who assert that "shared knowledge is *always* based on shared understanding" and that "there can never be shared knowledge without shared understanding; shared understanding is a local prerequisite for shared knowledge". Developing and maintaining shared understanding using "shared mental models" (Oehlberg, 2012, p.11) thus becomes the "common ground" under which knowledge sharing, knowledge integration and knowledge creation practices are cultivated and nurtured (Oehlberg, 2012, p.4; Gomes and Tzortzopoulos, 2018, p.475) and "lays the ground for future *actions*" (Mengis, 2007, p.42). *"Shared understanding"*, using *"shared mental models"*, is therefore viewed as the *"common ground"* and base foundation underpinning all knowledge sharing practices, and hence is positioned as the 'base' under the inverted triangle in Figure 7.10 and Figure 7.11.

***The Process of Developing Shared Understanding***

Developing and maintaining shared understanding is a collaborative process that presents both a challenge and opportunity in interdisciplinary collaborative teamwork, and requires team members to explicitly articulate their views, beliefs, interpretations and interests throughout the mHealth intervention app project and during all nine steps of the *"interdisciplinary collaborative process"* (framework main component 2, Figure 7.2) (Rosenkranz, Vranešić and Holten, 2014; Gomes, Tzortzopoulos and Kagioglou, 2016). To develop shared understanding, interdisciplinary team members' tacit knowledge needs to be made explicit through processes

of socialisation (dialogical interaction), externalisation (articulation), combination (mentalisation), and internalisation (subjective practical understanding) (Kosonen, 2015). Furthermore, by considering interdisciplinary team members' different disciplinary backgrounds (practice communities), expertise, past experiences and skills, as well as the context, situational setting and activity/task at hand, team members can begin to engage in iterative question-feedback-negotiation communication cycles as a process for creating shared understanding (Cash, Dekoninck and Ahmed-Kristensen, 2017). Moreover, gaining insight into the sources and motivators for different assumptions, interpretations and conflicting interests can also help build shared understanding (Oehlberg, 2012).

Overall, the process of developing and maintaining shared understanding is challenging and iterative, and although miscommunications and misunderstandings are natural emergent features of collaborative design, development and evaluation activities, they fundamentally hinder and impede productive interdisciplinary teamwork and constrain design solution innovation, and therefore need to be collectively uncovered and addressed by engaging in continuous formal and informal dialogical interactions and practical perspective-taking and perspective-making activities throughout the mHealth intervention app project lifespan (Uusitalo, 2015; Langley, Wolstenholme and Cooke, 2018).

***The Role of Boundary Objects in Supporting the Development of Shared Understanding***

"Boundary objects contribute significantly to the development of shared understanding, knowledge creation and innovative thinking" among diverse interdisciplinary collaborating team members and different objects support different knowledge and communication processes at different knowledge boundaries (Kanwal, et al., 2019, p.100). Boundary objects are key facilitators and mediators in supporting the development of shared understanding (as inputs) and, at the same time, are created and produced through the process of developing shared understanding (as outputs) (Mengis, 2007; Rosenkranz, Vranešić and Holten, 2014). In addition, boundary objects are indispensable and essential for performing knowledge transfer, translation and transformation processes across heterogeneous practice community boundaries (Carlile, 2002; 2004) and play a critical role in transforming knowledge, integrating knowledge, and generating (creating) new knowledge (Kosonen, 2015; Koskela, et al., 2016; Kanwal, et al., 2019). As new circumstances arise and differences, dependencies and novelties increase (upwards along the orange scale in Figure 7.10 and Figure 7.11), the knowledge gaps widen, leading to a loss of shared understanding between interdisciplinary collaborating team

members (Carlile, 2004; Stange, 2017). Boundary objects help shine a light on the differences, dependencies and novelties, and provide a common point of reference around (and through) which team members can explicitly articulate their tacit knowledge, internalised (conceptual and cognitive) perspectives, mental models, views, beliefs, assumptions, interpretations, values and (political) interests, thereby facilitating, mediating and supporting the team's process of developing shared understanding, creating shared models and (re)establishing common ground (Bittner and Leimeister, 2013; Rosenkranz, Vranešić and Holten, 2014; Kanwal, et al., 2019).

### 7.6.4 The Role of Boundary Objects (Knowledge Artefacts) in Knowledge

Boundary objects, also referred to as knowledge artefacts, are a core element of the proposed framework's *"knowledge"* component (Figure 7.10). As conveyed through Carlile's (2004) knowledge framework (Chapter 5), boundary objects are intricately entangled with knowledge sharing processes, are indispensable for developing shared understanding and overcoming knowledge boundaries between interdisciplinary collaborating team members localised within diverse communities of practice, and are integral to the success of mHealth intervention app projects (Oehlberg, 2012; Rosenkranz, Vranešić and Holten, 2014; Koskela, et al., 2016; Gomes and Tzortzopoulos, 2018).

In Figure 7.10, boundary objects (knowledge artefacts) are represented through three forms of illustration. Firstly, the small blue, yellow, green and purple circles on the syntactic, semantic and pragmatic bidirectional arrows, respectively, and on the shared understanding base, portray boundary objects as shared (multi-site) facilitators and mediators of knowledge flows betwixt actors on either side of the knowledge boundaries. Secondly, the small blue, yellow, green and purple circles within the two light grey communities of practice depict the employment and use of boundary objects by heterogeneous team members within their own localised (individual-site) communities. Thirdly, the magnified and zoomed-in larger blue, yellow, green and purple circles convey a "zoom" into the boundary objects (small circles) operating at the three knowledge boundaries, within the two localised communities, and at the shared understanding base. Notably, the boundary objects in Figure 7.10 are not prescriptive or exhaustive, although they do correspond to the illustrative examples in Figure 7.8 (Appendix L.1) and are relevant to the mHealth physical activity behaviour change intervention app project context.

In drawing an association between the boundary object (knowledge artefact) examples in Figure 7.10 and the boundary objects in Figure 7.8, it is important to emphasise and highlight

that the three boundary object categories (primary, secondary and tertiary) and two boundary object types (design and general) do not directly inform where knowledge artefacts fall within the three knowledge boundaries or the shared understanding base. Rather, it is the purpose and capability of a given knowledge artefact, within a given context/situational setting, that informs which knowledge boundary it falls in. For instance, secondary boundary objects can operate at the syntactic, semantic and/or pragmatic knowledge boundaries, separately or simultaneously (demonstrating their flexible, dynamic, transitional and shifting nature, Subsection 7.5.2.2). An example is the CALO-RE and BCT v1 taxonomies included in both the blue syntactic and yellow semantic magnified circles (Figure 7.10). Notably though, while direct associations cannot be assumed, primary boundary objects generally do operate at the pragmatic knowledge boundary since they tend to trigger, motivate and drive political discussions and negotiations, and typically pivot around interdisciplinary collaborating team members' values and interests.

Furthermore, it is important to note that while a given boundary object (knowledge artefact) may be developed with the intention to possess a certain knowledge boundary capability (such as supporting the creation of common meanings for translating knowledge), the object can fail and be ineffective if ill-suited to the actors' knowledge and skills, the process activity, or the context/situational setting (demonstrating their fallible nature, Subsection 7.5.2.2). In addition, although a given boundary object (knowledge artefact) may be developed with the intention to support capabilities at a certain knowledge boundary, it is not confined to addressing that boundary alone, and may be potentially useful at other knowledge boundaries; again depending on the actors, process and context. This blurry, flexible and somewhat unpredictable nature of boundary object (knowledge artefact) behaviour echoes the discussion in Section 7.5, which explains that the utility and value of boundary objects derives from interdisciplinary collaborating team members' (actors') symbolic interactionist and sociomaterial actions toward and with artefacts in pragmatic enacted use and context.

Another important point to emphasise is that boundary objects (knowledge artefacts) employed, utilised and created in mHealth intervention app projects should aim to function as "good enough", not all-inclusive absolute or perfect, common points of reference that adequately and sufficiently support interdisciplinary collaborating team members in sharing and assessing knowledge at a boundary; they are not "magic bullet" solutions for overcoming knowledge boundaries (Carlile, 2002, p.452; 2004). With these important points in mind as

caveats, the various role and examples of boundary objects (knowledge artefacts) illustrated at the three knowledge boundaries and shared understanding base (Figure 7.10) can be described.

***Boundary Objects (Knowledge Artefacts) at the Knowledge Boundaries and in Shared Understanding***

At the *syntactic knowledge boundary* (bottom blue bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Syntactic boundary objects need to be able to sufficiently transfer knowledge, process information and provide interdisciplinary collaborating team members with a common (shared) language to communicate, exchange, assess and share knowledge across heterogeneous practice community boundaries. A magnification into the blue syntactic circle in Figure 7.10 provides examples of syntactic boundary objects (corresponding to *"boundary objects"*, Figure 7.8) including a common glossary and the CALO-RE and BCT v1 coding taxonomies. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional syntactic boundary object (knowledge artefact) examples.

At the *semantic knowledge boundary* (middle yellow bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing and learning about knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Semantic boundary objects need to be able to sufficiently translate knowledge, make interpretations of meaning explicit (that is, help make tacit knowledge explicit) and provide interdisciplinary collaborating team members with common (shared) meanings to communicate, deliberate, assess and share knowledge across heterogeneous practice community boundaries. A magnification into the yellow semantic circle in Figure 7.10 provides examples of semantic boundary objects (corresponding to *"boundary objects"*, Figure 7.8) including: the BCW; standardised shared templates; standardised shared forms; standardised shared checklists; the mERA Checklist; the CALO-RE and BCT v1 taxonomies; and the Dyadic Lenses. In addition, shared (common) processes, and more specifically, the framework's proposed *"interdisciplinary collaborative process"* (second main component, Figure 7.2) functions at the semantic knowledge boundary. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional semantic boundary object (knowledge artefact) examples.

At the *pragmatic knowledge boundary* (top green bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing, learning about and

transforming knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Pragmatic boundary objects need to be able to sufficiently transform knowledge, generate "creative abrasions" and provide interdisciplinary collaborating team members with common (shared) interests to communicate, negotiate, assess and share political knowledge across heterogeneous practice community boundaries (Carlile, 2004, p.559; Uusitalo, 2015, p.43). A magnification into the green pragmatic circle in Figure 7.10 provides examples of pragmatic boundary objects (corresponding to *"boundary objects"*, Figure 7.8). Examples are: mHealth (physical activity) behaviour change intervention app prototypes, ranging from low- to high-fidelity, including manual and/or digital user interface design app screen mock-ups, sketches, storyboards, flow diagrams, wireframes, basic functional and interactive MVP apps, alpha app prototype versions, beta app prototype versions, 2D and 3D app prototyping simulations, and the final released mHealth (physical activity) behaviour change intervention consumer app. In addition, all interdisciplinary team and project documentation developed (and revised) throughout the interdisciplinary collaborative process (Table 7.1 and Table 7.3) will function at the pragmatic knowledge boundary because these documents inherently incorporate political negotiations, trade-offs and decision-making with regard to team members' different (and often conflicting) values and interests. Two pragmatic boundary object examples included in Figure 7.10 (green circle) are the shared interdisciplinary team document and the shared design vision solution document on the instantiated conceptual and technological mHealth intervention app design. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional pragmatic boundary object (knowledge artefact) examples.

At the *shared understanding* base (purple rectangle in Figure 7.10), boundary objects (knowledge artefacts) are *co-created* and *co-produced* by interdisciplinary collaborating team members during the interdisciplinary collaborative process (Table 7.1 and Table 7.3) to support, facilitate and mediate the development and maintenance of shared mental models and common understandings (Mengis, 2007; Kosonen, 2015; Melville-Richards, 2015; Uusitalo, 2015; Stange, 2017; Kanwal, et al., 2019). Shared understandings need be able to provide interdisciplinary collaborating team members with common ground to productively engage in knowledge sharing (transfer, translation and transformation), knowledge integration and knowledge generation (creation) practices and processes. Shared understanding co-created and co-produced boundary objects (knowledge artefacts) correspond to the nine steps of the interdisciplinary collaborative process (framework main component 2, Table 7.1 and Table 7.3). A magnification into the purple shared understanding circle in Figure 7.10 provides

examples of co-created boundary objects (corresponding to *"boundary objects"*, Figure 7.8) which generally include co-produced project, team, process and product documentation. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional shared understanding co-created boundary object (knowledge artefact) examples.

### 7.6.5 Knowledge: Application

#### 7.6.5.1 Guideline Recommendations for Applying Knowledge

Knowledge is a fundamental and indispensable contributor to the success of any given mHealth (physical activity) behaviour change intervention app project (Uusitalo, 2015) and is deeply ingrained and interwoven with the other three main and two supplementary framework components. The key challenge with knowledge, however, is that it is "localised, embedded and invested in practice" (Carlile, 2002, p.442), is often tacit in nature, lying implicitly in the minds of interdisciplinary collaborating team members (Kosonen, 2015), and is not always consciously and adequately considered and managed effectively, leading to hindrances and obstructions (Carlile, 2004; Tell, et al., 2017). For interdisciplinary teams to effectively communicate, coordinate, cooperate, collaborate, negotiate and achieve the mHealth intervention app project goals and objectives, and effectively overcome knowledge boundaries and develop shared understandings, interdisciplinary team members need to deliberately and consciously make their "sticky" tacit knowledge explicit (Tell, et al., 2017, p.48). Employing and using shared standardised templates (such as Appendix J.2) and shared guidelines (such as Appendix J.3) can support interdisciplinary collaborating team members' knowledge elicitation and explication process. Instead of proposing strict and rigid prescriptive guidelines for applying knowledge, optional guidelines recommendations are offered (Appendix M.2).

### 7.6.6 Knowledge: Summary and Knowledge Boundary Objects

Section 7.6 has provided a clipping (Figure 7.9) and detailed perspective (Figure 7.10) of the proposed Interdisciplinary mHealth App Design Framework's fourth main *"knowledge"* component. Corresponding to Figure 7.10, the *"nature and perspective"* of knowledge has been outlined, and the *"knowledge boundaries"*, *"knowledge processes"*, *"communication processes"* and *"knowledge boundary aims"* have been described. Figure 7.11 then elaborates on the role of actors, and particularly *"knowledge brokers"*, in interdisciplinary collaborating team projects, after which *"shared understanding"* and the role of *"boundary objects (knowledge artefacts)"* in knowledge have been discussed (with additional object examples

provided in Appendix M.1). Furthermore, optional *"guideline recommendations"* have been presented for applying the framework's knowledge component in practice (Appendix M.2), and references have been made to two boundary objects (Appendix J.2 and Appendix J.3).

Overall, the five *"knowledge"* component contributions, with two *"actors"* contributions, can be employed by mHealth intervention app project teams to serve as boundary objects for facilitating and mediating knowledge sharing and knowledge building practices, and supporting the development of shared understanding, shared mental models and common ground between interdisciplinary collaborating team members (stemming from heterogeneous practice communities). Like a golden thread, knowledge sews and weaves all of the proposed framework's components together into a project tapestry, and boundary objects (with embedded knowledge) can be employed, utilised and created to function as knowledge artefacts in supporting interdisciplinary collaborating teams' knowledge sharing, knowledge generation (creation) and knowledge integration practices, and also harnessed as knowledge artefacts for paving the way to creating and producing innovative mHealth (physical activity) behaviour change intervention app solutions. On a final note, the discussions in Section 7.6 have further described and demonstrated the complex and intricate pragmatic and sociomaterial and relationship entanglements between the framework's four main *"actors"*, *"knowledge"*, *"interdisciplinary collaborative process"* and *"boundary objects and supporting artefacts"* components, as well as the two supplementary *"project boundary"* and *"outcomes"* components (Figure 7.2).

## 7.7 Project Boundary and Outcomes

### 7.7.1 Project Boundary: A Detailed Perspective

Figure 7.12 provides a high-level, simplified capture of the *"project boundary"*, the framework's first supplementary component from Figure 7.2, which represents the delineated scope and demarcation of any given mHealth (physical activity) behaviour change intervention app project within a given context.

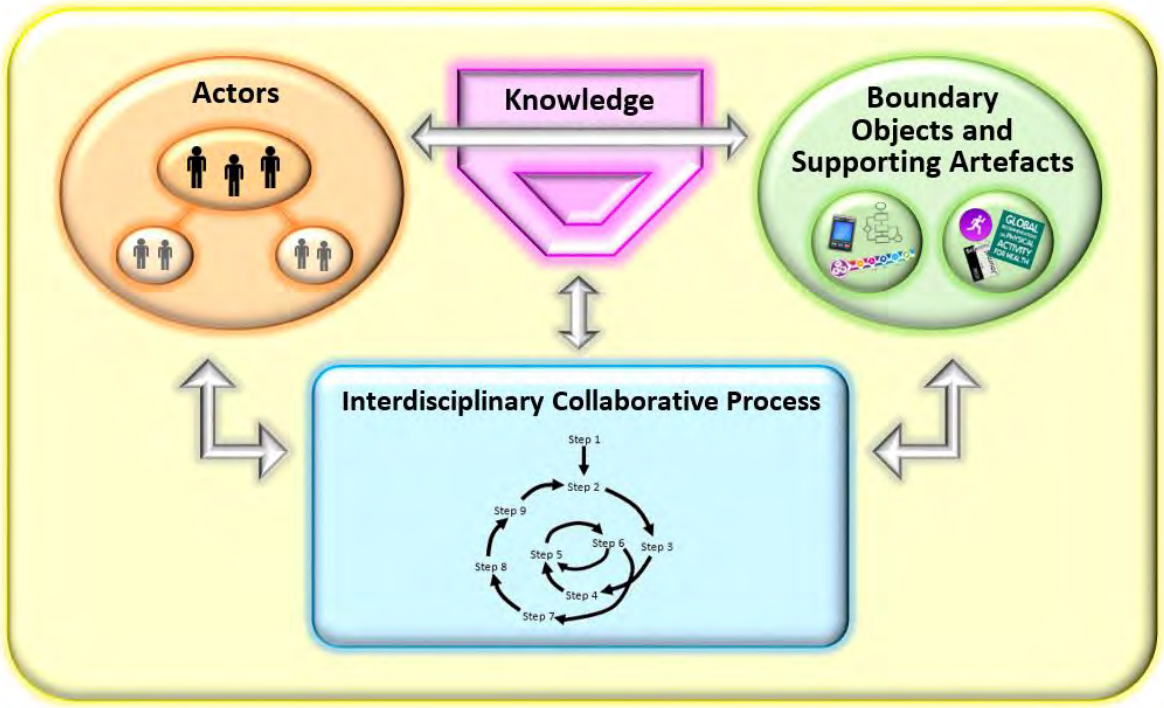



*Figure 7. 12: "Project Boundary": Supplementary Component 1 of the Proposed Framework [Source: Researcher's own construction]*

It is within the "*project boundary*" (depicted by the solid yellow rectangle in Figure 7.12) that a specific interdisciplinary collaborating team is established and formalised, a shared interdisciplinary collaborative process (and its comprising steps and activities) is carried out, a diversity of boundary objects and supporting artefacts are employed, utilised and created, and knowledge is shared and co-created. In Figure 7.12, the borderline and shaded yellow does not convey meaning other than to correspond with Figure 7.2, and the multi-colour shaded grey arrows and intricacies of the four main components have been removed for a high-level abstract illustration of the project boundary. Notably, the solid yellow borderline does not imply the project boundary as being definitive, fixed, rigidly defined or impermeable. Instead, in real world practice, the project boundary and its comprising components are, by nature, blurry and fuzzy, flexible, porous and permeable (Brown, Crawford and Darongkamas, 2000).

In addition, the solid yellow borderline (Figure 7.12) does not suggest that the project and its constituting components exist in isolation, nor is the project unaffected and uninfluenced by surrounding contextual, situational, cultural, historical and socio-environmental factors (Koskela, et al., 2016). Advancements in digital mobile and app technologies, introductions of new interdisciplinary evaluation methods, entering and exiting of new actors, natural disasters, and global circumstances (such as the novel coronavirus COVID-19 health pandemic outbreak)

are examples of external factors that exist outside the boundary of a project, yet may permeate through the project's boundary, influencing and impacting the project's progress and success.

The solid yellow borderline (Figure 7.12) does, however, convey that the boundary of a mHealth intervention app project should provide its constituting interdisciplinary collaborating team with sufficient project structure and scope to engage in collaborative knowledge sharing and heteropraxial process activities, and should help focus their shared team efforts towards producing an innovative mHealth (physical activity) behaviour change intervention consumer app product (Mengis, 2007; Oehlberg, 2012). Furthermore, it is within the yellow project boundary (Figure 7.12) that interdisciplinary team members (stemming from heterogeneous practice communities) partake in communication, coordination, cooperation, collaboration and negotiation practices that enable and foster mutual learning, shared understanding and joint problem solving, to produce innovative hybrid mHealth (physical activity) behaviour change intervention app product solutions. Moreover, it is within the boundary of a mHealth intervention app project that interdisciplinary collaborating teams share mutual (design) problem and solution spaces (boundary zones) and collectively develop their own team cultures, dynamics and interactive and sociomaterial pragmatic practices applicable to their given project and context. Lastly, given the constantly emerging and advancing mHealth intervention app landscape (which incorporates several diverse practice communities), the boundaries of a project (and its comprising components) remain adaptable, pliable and transformable over time as the project evolves throughout its lifespan.

### 7.7.1 Outcomes: A Detailed Perspective

Figure 7.13 provides a detailed perspective of the *"outcomes"*, the framework's second supplementary component from Figure 7.2, which represents the resulting effects that derive from the systemised pragmatic symbolic interactionist and sociomaterial praxes and entangled enactment of the four main components within a given mHealth (physical activity) behaviour change intervention app project boundary and context. In Figure 7.13, the two outcomes of the framework, namely the *"process outcome"* and *"product outcome"*, are categorised as primary and secondary project outcomes, respectively. The outcome elements have been informed by the critical theoretical analysis findings (Chapter 6, Section 6.5.1).

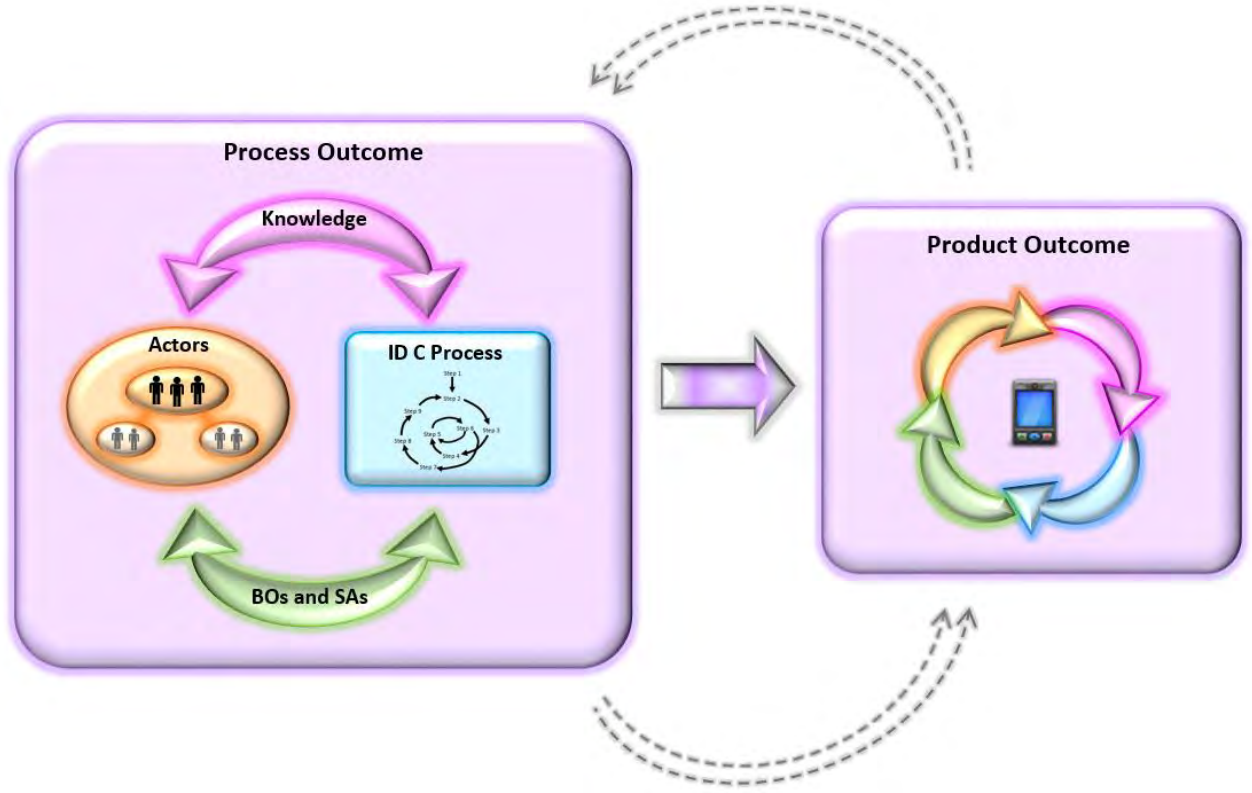



*Figure 7. 13: "Outcomes": "Process Outcome" and "Product Outcome": Supplementary Component 2 of the Proposed Framework*

*[Initialisms: ID – Interdisciplinary; C – Collaborative; BOs – Boundary Objects; SAs – Supporting Artefacts] [Source: Researcher's own construction]*

***Process Outcome***

The first "*process outcome*" (the left-hand side purple rectangle, Figure 7.13) aligns with one the proposed framework's key aims, which intends to provide interdisciplinary collaborating teams (orange circle) with an object-supported (green bidirectional arrow) and knowledge-integrated (pink bidirectional arrow) interdisciplinary collaborative process (blue rectangle) that guides the design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps. By referring to and applying the framework in practice, interdisciplinary collaborating teams can be supported through a series of processual steps and activities that promotes and cultivates collective communication, coordination, cooperation, collaboration and negotiation amongst multiple intersecting heterogeneous communities of practice.

Through the effective use of boundary objects and supporting artefacts, interdisciplinary collaborating team members are encouraged to acknowledge and integrate contributions from a rich diversity of disciplinary backgrounds and practice communities. Team members'

contributions can constitute many forms, including expert knowledge, skills, perspectives, interpretations of meaning, values, theories, frameworks, models, concepts, constructs, methods, tools, artefacts, instruments and activities. A boundary object supported approach to interdisciplinary mHealth intervention app design, development and evaluation essentially promotes, facilitates and mediates the sharing, integration, generation (creation) and transformation of knowledge across the boundaries of several fields; all of which are important, applicable and valuable to the production of innovate, persuasive and effective mHealth (physical activity) behaviour change intervention consumer app products. The interdisciplinary collaborative process in effect focuses team members' efforts and contributions towards achieving the team's shared vision and common project goal, which is ultimately to design and produce better and more effective interdisciplinary digital mobile consumer apps intended to deliver behaviour change interventions targeting the dual intra-interpersonal socioecological levels of health promotion.

***Product Outcome***

The second "*product outcome*" (the right-hand side purple rectangle in Figure 7.13) concerns the mHealth (physical activity) behaviour change intervention consumer app product that has been designed, developed and evaluated by the interdisciplinary team as an output result of the enacted object-supported and knowledge-integrated interdisciplinary collaborative process. The "*product outcome"* is also a resulting output of the mHealth intervention app project as a whole. The relational and associative effect between the process outcome and product outcome is illustrated by the unidirectional right-facing purple gradient shaded grey arrow in Figure 7.13. To clarify the relationship or association between the two outcomes, the interdisciplinary collaborative *process* (and project) directly and indirectly *effects* the mHealth (physical activity) behaviour change intervention consumer app *product* output. In more granular terms, the mHealth (physical activity) behaviour change intervention app "product" is a(n) (iteratively refined) material manifestation of interdisciplinary collaborative crystallised (design) knowledge sharing and knowledge integration, and heteropraxial design, development and evaluation "process" practices. The iterative nature of mHealth intervention app projects and interdisciplinary collaborative design, development and testing/evaluation processes and activities is illustrated by the two top and bottom double-dashed grey arrows flowing and cycling between the "process outcome" and "product outcome" subcomponents (Figure 7.13).

After the public release of a mHealth (physical activity) behaviour change intervention consumer app on the commercial app market, post-release market activities involve continuous improvement and continuous delivery practices (Tozzi, 2017; Mala, et al., 2019; Sucala, et al., 2020). Continuous tracking, monitoring and analysing (surveillance), (delta) testing, maintenance, improvement, delivery and updating practices are carried out for the remainder of the project's, team's, process's and product's lifespan (Francis, 2017; Peiris, Miranda and Mohr, 2018; Taylor, 2018). This post-release market continuous improvement/continuous delivery and iterative approach to mHealth (physical activity) behaviour change intervention consumer app production is illustrated by the four curved-arrow agile cycle revolving around the mobile app icon in the *"product outcome"* subcomponent in Figure 7.13. Essentially, the four curved-arrow agile cycle is made up of the orange *"actors"*, pink *"knowledge"*, blue *"process"* and green *"boundary objects and supporting artefacts"* curved arrows. The four curved-arrow agile cycle conveys that the iterative pragmatic symbolic interactionist and sociomaterial praxes of the project and process yield and produce updated mHealth (physical activity) behaviour change intervention consumer app versions over time (for the remainder of the project and product lifespan).

## 7.8 Relationships

The Interdisciplinary mHealth App Design Framework's four main and two supplementary components are interdependent and interrelated; they cannot be viewed as independent silos. All of the components exhibit a multi-reciprocal relationship, and throughout the lifespan of any given mHealth intervention app project, the six components are continuously influencing and building on one another. The shared common aims of mHealth intervention app projects, regardless of health behavioural context, strive to improve the production, output design and delivery of effective mHealth behaviour change intervention consumer apps targeting individuals at the dual intra-interpersonal socioecological levels of health promotion. To achieve these aims, the six components need to work conjointly and synergistically. This is because the interdependent and interrelated entanglements of the *"actors"*, *"interdisciplinary collaborative process"*, *"boundary objects and supporting artefacts"*, *"knowledge"* , *"project boundary"* and *"outcomes"* components (and their subcomponents) significantly impact the production, output design and delivery of mHealth behaviour change intervention apps, such as those targeting physical activity in individuals. The conjoint and synergistic functioning of these components can be better guided, supported and improved through the provision of comprehensive and innovative interdisciplinary frameworks (Blandford, 2019b; Taj, Klein and

van Halteren, 2019; Wang, 2019; Bul, et al., 2020; Damen, et al., 2020; Sellak and Grobler, 2020; Sucala, et al., 2020), such as the proposed framework artefact in this research project.

Throughout Sections 7.2 to 7.7, the complex and intricately interwoven pragmatic sociomaterial and symbolic interactionist entanglement of the framework's components (and subcomponents) has been consistently and meticulously reiterated, elaborated on and discussed, with demonstrative examples evidencing these entanglements in terms of the mHealth physical activity behaviour change intervention app project context. To avoid excessive repetition, this section simply provides an overview synopsis of the framework's main component relationships; essentially the golden thread that ties the components together.

In Figure 7.2, the multi-colour (orange, blue, green and pink) gradient shading on the four main bidirectional grey arrows nested within the *"project boundary"* represent a high-level abstract representation of the relationships between the four main framework components within any given mHealth intervention app project. The orange gradient shading in the three bidirectional grey arrows portrays *"actors"* as human, social relational and interactional carriers of *"knowledge"*, users of *"boundary objects and supporting artefacts"*, and enactors of the *"interdisciplinary collaborative process"* steps and activities. The blue gradient shading in the three bidirectional grey arrows convey how the *"interdisciplinary collaborative process"* is complexly interlaced with *"actors"* who are collaboratively guided by and enact on the shared process steps and heteropraxial activities with *"boundary objects and supporting artefacts"*, and how the *"interdisciplinary collaborative process"* serves as a pragmatic and processual carrier, translator, mediator and transformer for *"knowledge"* sharing and building between the heterogeneous *"actor"* communities. The green gradient shading in the three bidirectional grey arrows signify the pragmatic, artificial and sociomaterial entanglement of *"boundary objects and supporting artefacts"* as consistently employed, utilised and created by *"actors"* during all nine steps of the *"interdisciplinary collaborative process"*, and as sociomaterial and symbolic interactionist artefact holders, translators, facilitators and mediators of *"knowledge"* between *"actors"* of heterogeneous practice communities. The pink gradient shading in the four bidirectional grey arrows depicts how *"knowledge"* flows and transitions (and hence is shared, transferred, translated and transformed) between the *"actors"* and *"boundary objects and supporting artefacts"* during the whole *"interdisciplinary collaborative process"*. Essentially, *"knowledge"* – as a cognitive, conceptual and communication component that supports perspective sharing, sensemaking, learning and understanding between *"actors"* –

serves as a thread, sewing and weaving all of the framework's six components together into a mHealth intervention app project tapestry.

In Figure 7.2, the two unidirectional gradient-colour shaded grey arrows positioned outside of the yellow *"project boundary"* concern to the framework's two supplementary components. The yellow gradient shading in the larger unidirectional down-facing grey arrow depicts how, in a pragmatic reality, the crystallised sociomaterial and symbolic interactionist manifestations of the component entanglements within the *"project boundary"* make up, constitute and inform the *"outcomes"*. Lastly, the purple gradient shading in the smaller unidirectional right-facing grey arrow conveys how the first *"process outcome"* (on the left) informs and influences the second *"product outcome"* (on the right).

The Interdisciplinary mHealth App Design Framework's component relationships thus far have been illustrated and described in terms of Figure 7.2, but Figure 7.13 also provides a more abstract and high-level graphical representation of the framework's component relationships. In Figure 7.13, within the *"process outcome"* component, the *"actors"* employ, use and create *"boundary objects and supporting artefacts"* and share and build *"knowledge"* during the *"interdisciplinary collaborative process"* within a given mHealth intervention app *"project boundary"* (the latter of which is graphically implied). These same components function as iterative and agile cycles around the mHealth (physical activity) behaviour change intervention consumer app in the *"product outcome"* component, and there are iterative and reciprocal influences between all six components flowing through the two top and bottom double-dashed grey arrows.

Overall, in Figure 7.2, the colour-coded boundary lines of the framework's four main and two supplementary components are not solid, definitive, fixed or rigidly defined. Instead, all of the six component boundaries are blurred, fuzzy, flexible, porous and permeable. This indicates that mHealth intervention app projects in general, regardless of health behavioural context, and the interdependent and interrelationships of the framework's components do not exist in isolation, and do not only influence one another, but are also affected and influenced by the situational, cultural, historical, social, environmental and contextual factors surrounding any given project. For example, the impacts, disruptions and hindrances on interdisciplinary and collaborative work projects owing to the global novel coronavirus COVID-19 health pandemic outbreak (DeFilippis, et al., 2020; Garro-Abarca, Palos-Sanchez and Aguayo-Camacho, 2021).

In short, the relationships between the framework's components (and subcomponents) are complexly interwoven and intricately entangled, and the aims of mHealth intervention app projects cannot be achieved without acknowledging and understanding the multifaceted and multidimensional dynamic symbolic interactionist and sociomaterial entanglements of these components in a pragmatic reality.

## 7.9 Limitations

All frameworks, theories and approaches have limitations, which are important to critically identify and reflect upon. Firstly, it is paramount to acknowledge that there are usually "discrepanc[ies] between principles and practice" (Bertelsen, 2000, p.23) or tensions and "contradictions between prescription and praxis" (Bertelsen, 1998, p.59). This means that the way the proposed framework (DSR artefact) is intended for use in practice may be different to the way humans (researchers and practitioners) make sense of and apply the framework in real world practice (Bertelsen, 2000). Real world practice is also complicated by humans' different interpretations of meaning and various symbolic interactionist and sociomaterial factors within different contexts and situational settings. Moreover, the "actual" enactment and sensemaking (Bertelsen, 2000, p.23) of the proposed framework when pragmatically adapted to suit particular mHealth intervention app project contexts will be influenced by the heterogeneity, knowledge, skills, experience, political and power dynamics, and individuality of the interdisciplinary collaborating team members and practice communities involved.

Secondly, the framework's *"actors"* component acknowledges several communities of practice and fields of expertise, but does not directly contribute knowledge to all of these identified fields. This is largely with respect to the *"business and product development"* and *"computer sciences"* communities (differentiated by dashed boundary lines) in Figure 7.4. As discussed in Subsection 7.3.1.1, the framework acknowledges these areas of expertise as vital for informing and contributing to the production of well-designed and effective mHealth (physical activity) behaviour change intervention apps, but does not provide detailed insight and guidance for practice. Guidance and knowledge contributions focusing on the business (management, marketing, financing and strategising) and technical (programming, networking and connectivity, information architecture, privacy and security) aspects of mHealth (physical activity) behaviour change intervention apps can be pursued in future research.

A third limitation of the proposed framework concerns its implicit assumptions held with regard to *"actors"* component. The application of this framework assumes that persons employing, using and contextualising the framework are sufficiently knowledgeable and experienced knowledge brokers who are capable of leading and managing productive mHealth intervention app projects. It also assumes that these persons are willing to exercise considerable effort to apply the framework in practice and that these persons are willing to assist, mentor and guide less experienced and novice team members during the project lifecycle.

Fourthly, the framework's *"interdisciplinary collaborative process"* is noticeably and undeniably comprehensive and detailed. It has already been explicitly articulated, emphasised and substantiated that the proposed process intends to offer general and comprehensive, not rigid instructional or strictly prescriptive, guidance. The proposed process is flexible, adaptable and malleable to suit project, team and practice application. Details pertaining to its flexibility, with examples, have been discussed in Section 7.4.1 and in Subsections 7.2.1.2 and 7.4.2.3.

Fifthly, a contrary perspective may argue that the proposed framework's *"interdisciplinary collaborative process"* is not adequately detailed to inform real world practice. In other words, it may be argued that it lacks sufficient detail for the pragmatic application of all nine steps. Deployment (Step 7 in Table 7.1 and Table 7.3), for instance, could be argued as not providing adequate details as to "how" deployment activities and practices are carried out. This concern relays back to the second limitation discussed above, which acknowledges and highlights that not all areas of expertise and specialisation are comprehensively addressed and detailed in this thesis project; these detailed investigations can be carried out in future research studies.

Sixthly, it could be argued that the proposed framework's *"knowledge"* component is too broad and does not sufficiently integrate elements and factors pertaining to mHealth (physical activity) behaviour change intervention app project contexts. Again, deeper explorations and investigations into *"knowledge"* as a concept and construct in mHealth (physical activity) behaviour change intervention app product design and production can be conducted in future research. A possibly valuable approach to understanding the role of *"knowledge"* may be to carry out inductive case study research designs, which could yield richer information from practitioners and mHealth intervention app designers and developers in real world contexts and settings.

Lastly, as a seventh limitation, it is acknowledged that the framework will need to applied and evaluated in real world practice and empirical mHealth (physical activity) behaviour change intervention app project cases before it can be generalised to support other forms of digital technology health behaviour change intervention projects (such as wearable devices, web-based portals), other types of health behaviour (such as healthy eating, smoking cessation and sleep), or other forms of mHealth app projects (such as those targeting medical and clinical services or (communicable and non-communicable) disease management).

## 7.10 Conclusion

This chapter contributes to answering the third research sub-question by adopting the tri-composite theoretical framework (boundary object view) (Chapter 5) and using literature (Chapters 3 and 4) and the critical thematic and comparative theoretical analysis findings (Chapter 6) to develop and propose a conceptual framework artefact for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps targeting individuals at the dual intra-interpersonal socioecological levels of health promotion.

The proposed Interdisciplinary mHealth App Design Framework comprises six components. The four main components concern any given mHealth intervention app project's (1) *"actors"*, (2) *"interdisciplinary collaborative process"*, (3) *"boundary objects and supporting artefacts"*, and (4) *"knowledge"*. The two supplementary components include the (1) *"project boundary"* and (2) *"outcomes"*. There exists a complex and intricate pragmatic symbolic interactionist and sociomaterial relationship entanglement betwixt all six components and their comprising subcomponents. The framework's components (and subcomponents) function interdependently, conjointly and synergistically to guide, support, facilitate and mediate the interdisciplinary design and production of innovative and effective mHealth (physical activity) behaviour change intervention consumer apps. For each of the framework's six components, detailed diagrams, tables and examples have been provided, illustrating and depicting the sub-components and their interrelationships. In addition, to accompany the framework's four main components, several boundary objects have been proposed, which can be employed, referenced, used and adapted by interdisciplinary collaborating teams to guide and support their heteropraxial processual activity and knowledge sharing and knowledge building praxes. Moreover, the proposed framework artefact in and of itself serves as a boundary object that interdisciplinary collaborating teams can employ, reference, apply and adapt to guide and

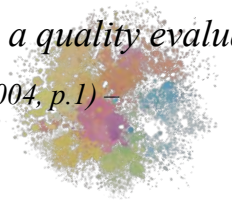
support their interdisciplinary efforts towards designing and producing innovative and effective mHealth (physical activity) behaviour change intervention consumer apps. To demonstrate the quality and trustworthiness of the proposed framework, and further particularise its significance and applicability to the physical activity promotion and mHealth app context, it is necessary to evaluate the proposed conceptual framework with "outsiders" who possess expert knowledge and practical experience from a heterogeneity of relevant disciplinary backgrounds; "provid[ing] an excellent opportunity for [the] researcher[] to discuss and receive feedback" (Jabareen, 2009, p.54).

# Chapter 8

## Research Methodology for Framework Evaluation

*The evaluation methodology is a tool to help one better understand the steps needed to do a quality evaluation.*

*– Baehr (2004, p.1) –*



## 8.1 Introduction

A framework for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth behaviour change intervention consumer apps is necessary for improving the output solution design and effectiveness potential of said apps. A community of practice, boundary object-supported and knowledge-integrated perspective of has been proposed as a novel approach to addressing the paucity of multi- and interdisciplinary approaches (Chapter 7). The proposed framework's first cycle of development was informed by the critical theoretical analysis findings (Chapter 6). As part of the iterative artefact development and refinement process, it is important to evaluate the framework's quality.

This chapter introduces and discusses the research methodology employed to conduct an evaluation study on the proposed Interdisciplinary mHealth App Design Framework. This research methodology is used to answer the fourth research sub-question: *"What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?"*. This ex-post evaluation study falls within Step 4 of the project's DSRM (presented in Chapter 2, Figure 2.5) (Vaishnavi and Kuechler, 2004; 2008; 2015).

The qualitative DSR linguistic interpretivist approach employed to evaluate the proposed framework in the context of mHealth physical activity behaviour change intervention consumer apps, is first discussed over two subsections. The first subsection clarifies the philosophical and paradigmatic assumptions underpinning the empirical study and its positioning within the broader research project. The second subsection details the linguistic interpretivist approach in terms of the DSR artefact evaluation framework, the ontology-based conceptual meta-model evaluation approach, and the linguistic interpretivist conceptual meta-model evaluation approach procedure. Thereafter, the interview survey strategy is selected and justified in relation to other research strategies. Following this, the qualitative interview data collection design is discussed, outlining the empirical study research question and objective, unit of analysis, research instrument, sampling technique, and the interview questions, guidelines and materials. The data collection method and thematic data analysis method are then described. Lastly, data validation, ethical considerations, and limitations for the empirical study are outlined.

## 8.2 Research Approach

### 8.2.1 Qualitative Artefact Evaluation in Design Science Research

A qualitative DSR linguistic interpretivist approach is employed to evaluate the proposed Interdisciplinary mHealth App Design Framework. Qualitative research offers insight into human behaviour – a pathway for understanding peoples' experiences, thoughts, meanings, emotions, attitudes and relationships (Mohajan, 2018). Its assumption that "reality is constructed by individuals interacting with their social worlds" affords an exploration and intellectualisation of subjective perceptions, social processes and contextual factors that characterise a particular group of people, situation or setting (Merriam, 1998, p.6). Adopting a qualitative approach to artefact evaluation provides a means of investigating and understanding the ways in which expert researchers and practitioners interpret and make sense of the processes, objects and knowledge sharing activities relevant to the design, development and evaluation of mHealth physical activity behaviour change intervention apps. A qualitative evaluation design allows for the elicitation of implicit, tacit and local knowledge that is specific to the mobile app platform and the physical activity context (Mohajan, 2018).

Qualitative research in the information systems discipline is valued within the interpretivist and pragmatic paradigms (Goldkuhl, 2004; 2012a; 2012b; 2020). Philosophically, interpretivism views the ontological nature of reality as subjective, complexly rich, multiple and socially constructed through relativism and human lived experience (Goldkuhl, 2012a; 2012b; Okesina, 2020). The epistemological acquisition of acceptable knowledge is understood as subjective and interpretive, and the axiological positioning and role of a researcher is instrumental to interpretations of findings and contributions, value-bound, reflexive and inseparable from the life-world (Goldkuhl, 2012a; 2012b; Saunders, Lewis and Thornhill, 2016). In comparison, pragmatism views the ontological nature of reality as practical, complexly rich, changeable and in a constant state of becoming through human action (Goldkuhl, 2012a; 2012b; Okesina, 2020). The epistemological acquisition of acceptable knowledge is understood as practical and problem-solving oriented, and the axiological positioning and role of a researcher is value-driven, reflexive, and initiated and sustained by their beliefs and doubts (Goldkuhl, 2012a; 2012b; Saunders, Lewis and Thornhill, 2016).

While interpretivism and pragmatism are often regarded as distinct paradigms by some researchers, an interpretivist-pragmatic hybrid fusion is arguable in information systems DSR, particularly in symbolic interactionism and sociomaterialism (Blumer, 1969; Orlikowski,

2000; 2007; Goldkuhl, 2012a; 2012b). Goldkuhl (2012b, p.11) describes the common ontological assumption link governing interpretivism and pragmatism as "meaningful action based in evolutionary social interaction" where, in information systems and DSR, "the practical and material character of the world emerges as equally important". Although, distinguishably, interpretivism values understanding in and of its own right, and pragmatism values understanding as an instrument to practical action and change, both paradigms share an orientation towards understanding (Goldkuhl, 2012a; 2012b). Furthermore, Goldkuhl (2004, p.21) explains that, "for a pragmatic IS researcher, an interpretive stance is unavoidable", and that their enquiries are not only about what people think of the world, but also what they do, as well as how actions can be improved (such as those relevant to the design of mHealth physical activity apps). By employing an interpretivist qualitative approach to artefact evaluation within the broader, overarching pragmatic study (Figure 8.1), an empirical investigation can be carried out to identify and determine the mHealth physical activity app context specific components deemed relevant to the Interdisciplinary mHealth App Design Framework. This philosophical orientation provides an opportunity to gain an understanding of the complexly rich, multiple subjective points of view and interpretations of knowledge experts and industry practitioners in relation to the mHealth physical activity app design process, and gain an understanding of the practical objects (boundary objects and supporting artefacts) utilised and knowledge sharing activities typically performed during the interdisciplinary collaborative process.

Figure 8.1 provides a graphical illustration of the qualitative approach employed for evaluating the proposed artefact, positioned within Step 4 ("evaluation") of the overall study's DSRM (outlined in Chapter 2). The adoption of an interpretivist perspective within the broader pragmatic DSR study is portrayed in the rightmost column (Figure 8.1). A hybrid cognitive reasoning strategy – comprising a combination of deductive and inductive reasoning – is employed in the evaluation study (introduced and detailed in Chapter 2). Deduction informs the data instrument's composition and the theory-driven coding framework for evaluating the proposed framework's components (Crabtree and Miller, 1992; 1999; Gregory and Muntermann, 2011). Induction allows the data to "speak to the theorist [researcher]" through gists that focuses their attention to detect any theoretical-contextual tensions and resolutions (refer to Chapter 2 for a detailed explanation) (Shepherd and Sutcliffe, 2011, p.368).

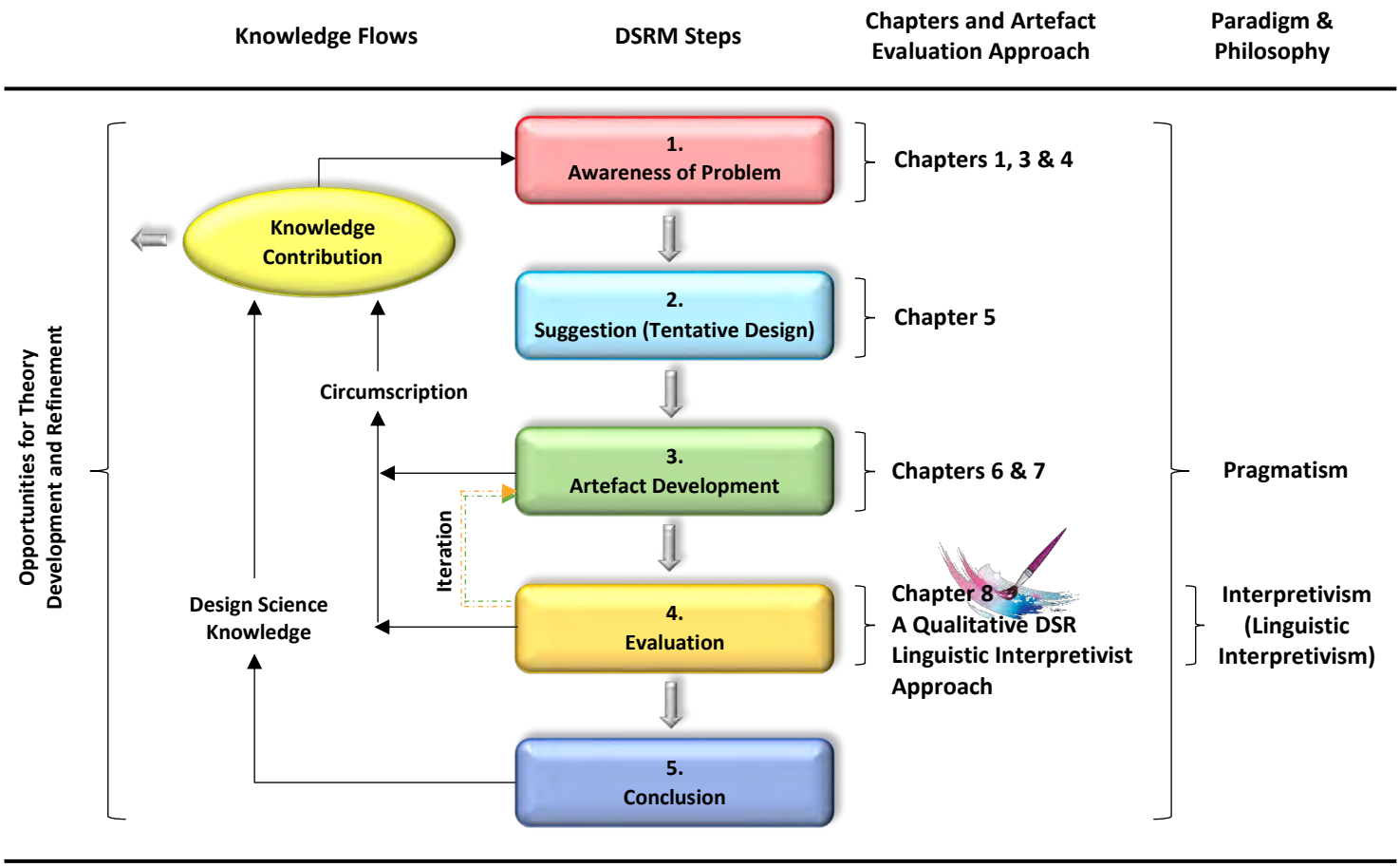



*Figure 8. 1: DSRM: Evaluation: A Qualitative DSR Linguistic Interpretivist Approach to Artefact Evaluation [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

Artefact and theory evaluation is a "crucial component" of the DSR process (Hevner and Chatterjee, 2010, p.109; Baskerville, et al., 2018) and involves the rigorous demonstration of the quality of a design artefact using credible and well-executed evaluation methods (Venable, Pries-Heje and Baskerville, 2016). Depending on the goals of the research project, the stage of the DSR process and the type of artefact contribution, a selected evaluation method and evaluation study design can vary considerably (Venable, Pries-Heje and Baskerville, 2016). Peffers, et al. (2012) recognises a DSR framework artefact contribution as a "meta-model". A DSR meta-model artefact can be described as an abstraction and representation of a problem application domain; a prescriptive theory for guiding problem solving in real world design situations (Hevner, et al., 2004; Peffers, et al., 2012). The ex-post evaluation of the framework (DSR meta-model artefact) in a particularised context (the mobile app platform and physical activity health domain) is necessary for providing evidence for its relevance and contribution to the interdisciplinary mHealth app design and information systems knowledge bases (Pries-Heje, Baskerville and Venable, 2008).

According to Becker, Niehaves and Pfeiffer (2008a), the evaluation of conceptual meta-models as proposed artefacts in information systems is of scientific and practical significance and a necessity. The quality of conceptual meta-models and their domain application has a notable impact on other information technology and systems artefacts (such as the solution design of mHealth behaviour change apps in general), has sizeable economic consequences, and if inadequate or flawed, can lead to problems in implemented systems projects (Pfeiffer and Niehaves, 2005; Becker, Niehaves and Pfeiffer, 2008a). Although there exists some empirical work on the development of approaches and criteria for evaluating the quality of conceptual meta-models in information systems DSR (Hevner, et al., 2004; Venable, Pries-Heje and Baskerville, 2016), terminological systems such as domain languages (which are referred to and used within conceptual meta-models) provide a representative function for denoting entities in real world domains (Becker, Niehaves and Pfeiffer, 2008a).

### 8.2.2 Design Science Research Artefact Evaluation with Linguistic Interpretivism

A philosophically sound, ontology-based linguistic interpretivist approach, grounded in information systems DSR theory, is employed to frame the ex-post evaluation study of the proposed conceptual meta-model artefact (Interdisciplinary mHealth App Design Framework) (Becker, Niehaves and Pfeiffer, 2008a). Describing this approach requires: (1) an explanation of the *DSR artefact evaluation framework* for assessing the quality of a conceptual meta-model; (2) a introduction of an *ontology-based approach* to conceptual meta-model artefact evaluation; and (3) a detailed description of the *linguistic interpretivist approach procedure* to conceptual meta-model artefact evaluation, which comprises language (re)construction, ontological evaluation and interpersonal verification activities.

#### 8.2.2.1 The Design Science Research Artefact Evaluation Framework: Conceptual meta-Models

A conceptual meta-model (framework) is a representation of an application domain expressed in semi-formal, mostly graphical language with the purpose of facilitating information systems design and development projects (Pfeiffer and Niehaves, 2005; Peffers, et al., 2012). Conceptual meta-models consist of a model core (with inter-model links and model statements) and an intended application domain (Pfeiffer and Niehaves, 2005). The model core is made up of model statements and inter-model links (Pfeiffer and Niehaves, 2005). A model statement comprises a model element structure (graphical arrangement of the model elements and their

connections among each other) and a terminological structure (the constructs and application domain terms applied in the model) (Pfeiffer and Niehaves, 2005). The element structure uses the terminological structure to express the content of the model, and the particular arrangement of the model elements and their relations expressed via the modelling language constructs and application domain terms (inter-model links), which in turn represents the proposition and empirical claim of the conceptual meta-model (Pfeiffer and Niehaves, 2005). The intended application domain refers to the environment the conceptual model aims to represent and describe (Pfeiffer and Niehaves, 2005).

The quality evaluation of an information systems DSR artefact (conceptual meta-model) should consider: *(1) the structure of the artefact* (its configuration and information space); *(2) the evaluation criteria* (the domain-specific information space aspects used to determine the artefact's quality); and *(3) the evaluation approach* (the guiding assessment procedure, which results in a decision as to whether the artefact meets the evaluation criteria based on the information space) (Pfeiffer and Niehaves, 2005; Becker, Niehaves and Pfeiffer, 2008a).

***The Structure of the Artefact***

The *structure of a conceptual model (artefact)* can be defined in terms of its theoretical core (information space), key constructs and a description of its intended application domain (Becker, Niehaves and Pfeiffer, 2008a). The theoretical core and key constructs of the Interdisciplinary mHealth App Design Framework are described in Chapter 7. The intended application domain, the physical activity health domain, is described and explored primarily in Chapters 3 and 4, but also filters into the critical review and analysis conducted in Chapter 6.

***The Evaluation Criteria***

The *evaluation criteria* can be guided by the guidelines for modelling developed by Schütte and Rotthowe (1998), which provides criteria catalogues for assessing and determining the quality of conceptual meta-models. Evaluation principles and criteria for conceptual meta-models include construction adequacy, language adequacy, clarity, economic efficiency, systematic design, and comparability (Schütte and Rotthowe, 1998). In this empirical study, the proposed framework will be evaluated against three criteria: *(1) construction adequacy*, *(2) language adequacy*, and *(3) clarity*.

The first criterion, *construction adequacy* (also referred to as reality adequacy), describes the comparative accuracy of a conceptual meta-model with the reality of the problem and proposed solution space (Schütte and Rotthowe, 1998). The construction quality of a model requires that consensus be achieved between the model developer (researcher) and persons relevant to the problem and solution domain (expert researchers and practitioners) (Schütte and Rotthowe, 1998). Given the subjective and interpretive nature of conceptual models, and the multifaceted nature of the interdisciplinary mHealth app field in particular, definite consensus regarding the real world problem and solution representation is a notable challenge and not practically attainable (Schütte and Rotthowe, 1998). Adequate consensus agreement is therefore deemed a satisfactory verification of the conceptual model's accurate representation of the problem and solution reality (Schütte and Rotthowe, 1998), catering for the utility aspect of conceptual model and its intersubjective view of truth (Becker, Niehaves and Pfeiffer, 2008b).

The second criterion, *language adequacy*, concentrates on the suitability, comprehensibility and accuracy of the semi-formal (artificial) language applied in the conceptual meta-model (Schütte and Rotthowe, 1998). Although linguistic terminology can be open to subjective interpretation (due to different perspectives and contexts), language suitability and consistency between the meta-model and its intended application domain is necessary for informing (interdisciplinary collaborative mHealth app design) practice. As is the case with construction adequacy, adequate language consensus agreement is regarded as a satisfactory verification of the conceptual model's element structure, terminological structure and inter-model links (Schütte and Rotthowe, 1998). An adequate consensus on language caters for the utility aspect of conceptual model and its intersubjective view of truth (Becker, Niehaves and Pfeiffer, 2008b).

The third criterion, *clarity*, refers to the comprehensibility and explicitness of the conceptual meta-model, with regard to its hierarchical decomposition, elemental arrangement and interrelation (layout design) and filtering of information (Schütte and Rotthowe, 1998). Clarity supports the lucidity of the proposed conceptual meta-model when applying it to a particular application domain. While it can be challenging to obtain absolute clarity for comprehensive and complex meta-models (as is the case with the proposed framework), the provision of accompanying guidelines and recommendations for use can support better comprehensibility and pragmatic application in project contexts (Schütte and Rotthowe, 1998).

***The Evaluation Approach***

The *evaluation approach* details the procedure for assessing the quality of the conceptual meta-model, and results in a decision as to whether the proposed DSR artefact meets the evaluation criteria based on the information space (Becker, Niehaves and Pfeiffer, 2008a). Essentially, it details evaluation planning (including the objectives, methods and criteria for evaluation) and the process for validating the conceptual meta-model (Becker, Niehaves and Pfeiffer, 2008b). Using Unified Modelling Language 2.0 (Hamilton and Miles, 2006), Figure 8.2 provides a simple activity diagram, depicting the three main process activities from meta-model construction (start activity, Chapter 7) to evaluation planning (this chapter) to meta-model verification (final activity, Chapters 9 and 10).

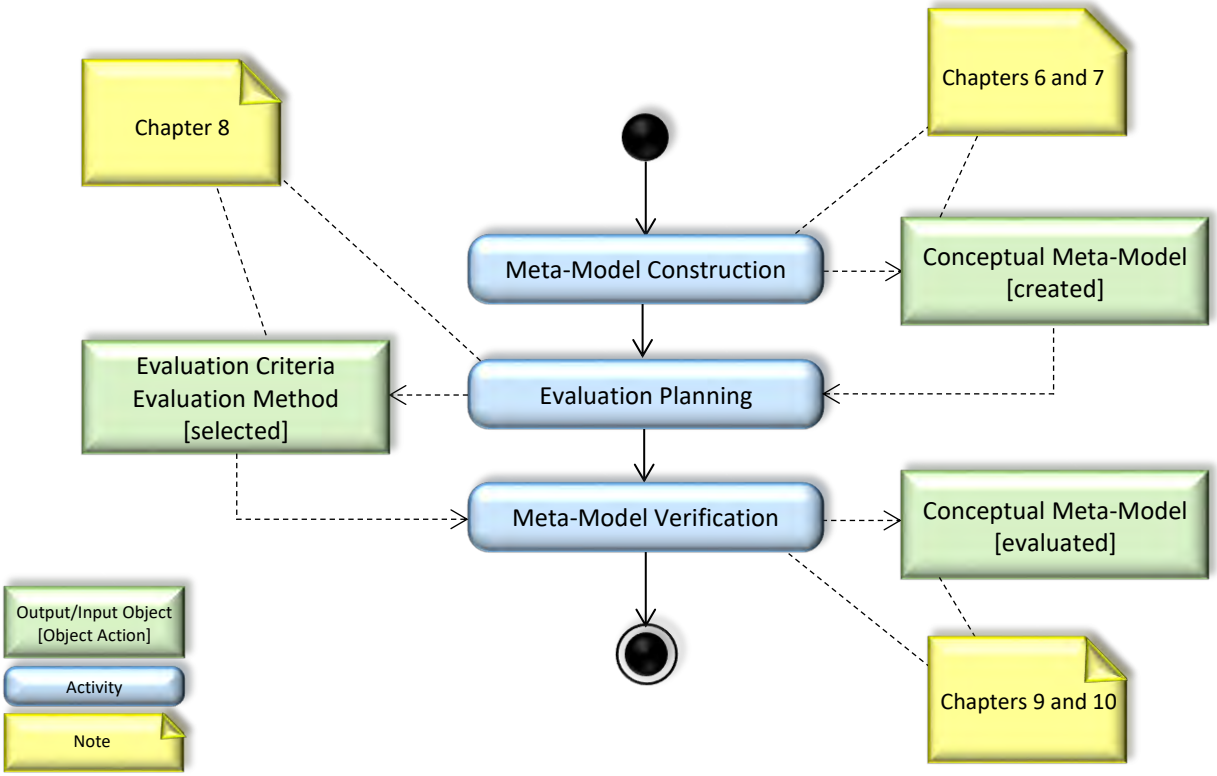



*Figure 8. 2: The Conceptual meta-Model Artefact Evaluation Process [Source: Adapted from Becker, Niehaves and Pfeiffer (2008b)]*

### 8.2.2.2 An Ontology-Based Approach to Evaluating Conceptual Meta-Models

Conceptual meta-models are developed using two languages: a modelling language and a domain language (Pfeiffer and Niehaves, 2005; Becker, Niehaves and Pfeiffer, 2008a). On the one hand, a modelling language provides a high-level abstraction of constructs and formal (or semi-formal) procedures (Becker, Niehaves and Pfeiffer, 2008a). The proposed framework

(meta-model) in Chapter 7 is described using domain-driven modelling language. This means that, although informed by some aspects of mHealth physical activity app theory and literature, the framework predominantly provides a high-level interdisciplinary approach to mHealth behaviour change intervention app design, development and evaluation in general. On the other hand, a domain language provides terms, concepts and vocabulary relating to a particular real world application domain, specially physical activity (Becker, Niehaves and Pfeiffer, 2008a). A domain ontology specifies a common and shared understanding of a specific domain of interest, and can be used as an instrument to (partly) represent a domain language (Becker, Niehaves and Pfeiffer, 2008a). The empirical study described in this chapter aims to explore the domain language used by knowledgeable and experienced researchers and practitioners in mHealth behaviour change intervention app design, development and evaluation for physical activity in particular, in order to refine and enhance the Interdisciplinary mHealth App Design Framework (artefact) based on the evaluation findings (Chapter 10).

There are, however, two important caveats to note with regard to an ontology-based approach to evaluating conceptual meta-models. Firstly, not all domain language terms and concepts can be formalised into a domain ontology, which means, in general, that a domain ontology seldom (if ever) comprises all terms, concepts and vocabulary employed within a domain language (Becker, Niehaves and Pfeiffer, 2008a). Secondly, a valid and quality conceptual meta-model may only refer to a small part of an existing domain language's terms and concepts (Becker, Niehaves and Pfeiffer, 2008a). This twofold challenge manifests as an incongruence between ontological and conceptual model statements (Becker, Niehaves and Pfeiffer, 2008a). On the flip side, Becker, Niehaves and Pfeiffer (2008a; 2008b, p.240) argue that the terms and concepts of a particular domain ontology and conceptual model "do not necessarily have be the same (congruent)". By not necessitating an ontology to be normative or complete, conceptual meta-model statements can be evaluated against domain ontology statements (Becker, Niehaves and Pfeiffer, 2008b). Since a domain language comprises a myriad of terms and concepts, only a few terms and concepts can be explicated in form of a domain ontology, and conceptual meta-models can only refer to a limited number of terms and concepts (Becker, Niehaves and Pfeiffer, 2008b). Therefore, instead of evaluating an information systems conceptual meta-model in its entirety and aiming for domain language completeness (which is impossible), it can rather be evaluated using an ontology-based linguistic interpretivist approach, which incorporates the process of interpersonal verification (Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008b; Pfeiffer, 2008).

#### 8.2.2.3 A Linguistic Interpretivist Approach to Evaluating Conceptual Meta-Models

Linguistic interpretivism provides a philosophically sound, ontology-based means of bridging the gap in conceptual meta-model evaluation (Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008a; 2008b). It also offers a theoretical foundation for a subjectivist epistemological position in conceptual meta-model evaluation by concentrating on the social artefacts of speech and language that people (such as domain expert researchers and practitioners) employ when constructing knowledge (Becker, Niehaves and Pfeiffer, 2008b). Initially described as the 'school of methodical constructivism' (Kamlah and Lorenzen, 1984), linguistic interpretivism can be adopted as a philosophical underpinning for assuming a critical consensus-orientated interpretivist approach to conceptual meta-model evaluation (Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008a; 2008b). A consensus-orientated approach can be leveraged to address alternate interpretations of words as terms and concepts, and hence overcome miscommunications and misunderstandings, especially between heterogeneously positioned researchers and practitioners (Becker and Niehaves, 2007). Essentially, a linguistic interpretivist consensus-orientated approach to evaluating the proposed framework (meta-model artefact) allows the researcher to consult with domain specialists in the field of mHealth physical activity behaviour change intervention app design as a means to elicit physical activity domain language that can be formalised as ontological mappings and conceptual statements in the framework. The result of this process yields a more context-specific validation of the framework (demonstrating an iteration within the DSRM, Figure 8.1).

Epistemologically, linguistic interpretivism holds the view that subjects subjectively (re)interpret and (re)produce reality through language representations and practices, and that the way specific real world situations are perceived is simultaneously shaped by, and reconstructed through, language and speech artefacts (subjectivism and constructivism) (Kamlah and Lorenzen, 1984; Becker and Niehaves, 2007). Language provides terms, concepts and semantic categories that reconstruct human cognition, which in simple practical terms, means that a subject's language and vocabulary influences the way they perceive, interpret and make sense of reality (and hence, the way actors cognitively perceive, interpret and make sense of a design problem and solution space) (Becker and Niehaves, 2007). Intellect and experience are both viewed as sources of cognition, thoughts are believed to be meaningless without content, and cognitions are declared blind if not linked to linguistic terms (Kantianism) (Becker and Niehaves, 2007). True cognition is achieved through consensus theory of truth and

semantic theory of truth within a linguistic community (that is, a subjectivist truth; not a positivistic, objective truth) (Becker and Niehaves, 2007).

A linguistic community is comprised of actors that share a specific language (Becker and Niehaves, 2007); similar to how, in community of practice theory, members within a specific community share common language and meaning interpretations (apparent in the discussions in Chapters 4, 5, 6 and 7). Individuals can form part of many linguistic communities at any given point in time; however, the linguistic community of interest in this empirical study is particularly concerned with members constituting part of the shared mHealth physical activity app design, development and evaluation linguistic community. Methodologically, linguistic interpretivism views that conceptual meta-models can contain both a priori and empirical knowledge, and that cognitions can be achieved and verified through meta-model creation (Chapter 7), empirical study (Chapter 8), and through deductive and inductive cognitive thought processing (Becker and Niehaves, 2007). This methodological view complements the DSRM and reasoning strategy employed in this study (Chapter 2, Section 2.3.3.2).

Conceptual meta-model and true cognition verification is based on the process of ontology-based statement evaluation and semantic-based interpersonal verification (Kamlah and Lorenzen, 1984; Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008a; 2008b). The conceptual meta-model can be logically decomposed through deductive thought processing until its formalised linguistic statements are accessible as elemental statements for the purposes of truth verification (Becker and Niehaves, 2007). This activity is referred to as ontological mapping (Becker, Niehaves and Pfeiffer, 2008a). In other words, the formal linguistic statements of the proposed framework are broken down into elemental linguistic statements that can be tested and verified by members of the mHealth physical activity app design, development and evaluation linguistic community. According to Kamlah and Lorenzen (1984) and Becker and Niehaves (2007), the main data collection instruments that can be used to carry out this verification process are interviews, observations, experiments and the interpretation of texts, with interviews being the most advantageous (selected and discussed later in Section 8.4). The conceptual model statements are either (a) validated through ontological statement evaluation, in which case all conceptual model statements are determined to be true in the context of the domain ontology, or (b) identified as containing semantic deficiencies, in which case the accessible elemental statements are identified and

(re)constructed through interpersonal verification, and subsequently formalised into the conceptual model's domain-language-based ontology (Becker, Niehaves and Pfeiffer, 2008a).

*Interpersonal verification* is the process of confirming and validating a conceptual meta-model's statements by obtaining consensus with one or more members of a relevant specific linguistic community regarding commonly understood terms, concepts and statements (statements which use known terms) (Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008a). Clarifying shared definitions and interpretative meanings for terms and concepts (through interpersonal verification) is necessary for the incremental testing and (re)construction of the framework's elemental and conceptual statements (Becker, Niehaves and Pfeiffer, 2008a). Reaching an explicit agreement with respect to a term's and concept's meaning and practical usage ensures that a common knowledge is verified, thus directly linking semantics and pragmatics accordingly (Kamlah and Lorenzen, 1984; Becker, Niehaves and Pfeiffer, 2008a).

The process of interpersonal verification is therefore an extension of the ontological evaluation of conceptual meta-models (Becker, Niehaves and Pfeiffer, 2008a; 2008b). As discussed in Subsection 8.2.2.2, domain ontologies provide a valuable means of evaluating conceptual meta-models. However, since domain ontologies cannot fully cover the content of a conceptual meta-model's statements, the philosophically sound ontology-based process of interpersonal verification (nested within the linguistic interpretivist approach) provides an empirical means for addressing this challenge (Becker, Niehaves and Pfeiffer, 2008a; 2008b). The terms, concepts and statements (which use known terms) that make up a conceptual meta-model can therefore be tested and verified by a domain-language-based ontology that only partly covers a conceptual meta-model's elemental and conceptual statements (Becker, Niehaves and Pfeiffer, 2008a; 2008b). In essence, interpersonal verification provides a means for evaluating statements, and the result findings of an empirical interpersonal verification process (such as interviews) can be used to validate and/or (re)construct the formalised domain-language-based ontology to enable a closed knowledge-loop (Becker, Niehaves and Pfeiffer, 2008a; 2008b). A linguistic interpretivist approach to artefact evaluation thus provides a theoretical basis for analysing terminological systems (domain languages) that are referred to and utilised within conceptual meta-models (Pfeiffer and Niehaves, 2005; Becker, Niehaves and Pfeiffer, 2008a). The ontology-based linguistic interpretivist approach to evaluating the Interdisciplinary mHealth App Design Framework (conceptual meta-model artefact) is summarised in Table 8.1.

*Table 8. 1: The Linguistic Interpretivist Approach Applied for Evaluating the Framework [Source: Adapted from Becker, Niehaves and Pfeiffer (2008a)]*

| | Perspective Themes | Description |
|---|---|---|
| **Language Construction** | Shared definitions and meanings | Definitions and meanings (semantics) for terms and concepts are clarified. Definitions may incorporate other known terms. The practical usage (pragmatics) for terms and concepts are explicated. |
| **Ontological Evaluation** | Conceptual meta- model decomposition | The conceptual meta-model is decomposed into elemental statements and terms. |
| | Ontological mappings | The conceptual meta-model's elemental statements (and its terms) are mapped with statements contained by the domain ontology. |
| | (a) Ontology-based statement evaluation | Possibility (a): All statements (and terms) made in a conceptual meta-model are covered by a domain ontology. A conceptual meta-model statement is assessed in terms of whether it is true in the context of the domain ontology. |
| **Interpersonal Verification** | (b1) Identification of semantic deficiencies | Possibility (b): Semantic deficiencies are identified in the domain ontology, and are elaborated on. This might result in a statement and/or a term not being fully covered in the domain ontology. |
| | (b2) Interpersonal verification | The logical decomposition of a conceptual meta-model's statements until they are accessible as elemental statements for the purpose of interpersonal verification. Verbal communicative discussions with one or more members of the relevant linguistic community are carried out to obtain consensus on the truth or non-truth of each elemental statement. Interviews are an advantageous data collection instrument to achieve this. |
| | (b3) Revision of domain ontology | The result findings of the interpersonal verification process are formalised into the domain-language-based ontology to enable a closed knowledge-loop. |

## 8.3 Research Strategy

An interview survey strategy is employed to evaluate the proposed Interdisciplinary mHealth App Design Framework. The survey strategy can be used for qualitative exploratory research within the DSRM, and is best suited for studies that target individual people for providing information on the unit of analysis (Hevner and Chatterjee, 2010; Bhattacherjee, 2012). Depending on how data is collected, a survey strategy can be divided into two broad categories, namely questionnaire surveys and interview surveys (Bhattacherjee, 2012; Gubrium, et al., 2012). As for the former category, the concept of a survey strategy is often understood as solely falling within quantitative research and is generally associated with large-scale questionnaires as a data collection method (Saunders, Lewis and Thornhill, 2016). This is a misconception and disregards the validity of the second latter category, which is less widely known and referred to in research projects (Bhattacherjee, 2012).

In information systems and the social sciences, a survey strategy can also refer to qualitative research and the use of "interview surveys" as a data collection method, including instruments such as personal interviews, online interviews, telephonic interviews and small-scale focus

group interviews (Bhattacherjee, 2012, p.74). While the key objective for questionnaire surveys is to generalise representative sample findings to a population (Creswell, 2014), the objective for interview surveys is to gather richer contextual data from smaller samples that generates findings for representing the phenomena and for the purpose of testing, improving and building theory (Bhattacherjee, 2012; Gubrium, et al., 2012). The empirical framework evaluation study in this research project aims to achieve the latter. That is, a deeper contextual understanding of the mHealth physical activity app domain with regard to the actors, objects (artefacts), knowledge and processes (and activities) associated with the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps. Another distinction between the two categories is that questionnaires are completed in (hand or electronic) writing by respondents, whereas interviews are completed by the researcher based on verbal responses provided by respondents (Bhattacherjee, 2012). This research study's empirical evaluation implements the latter method for capturing participants' responses.

In comparison to other available research strategies, the survey strategy is deemed the most appropriate fit given the objective of the artefact's evaluation. Other possible qualitative strategies include ethnography, grounded theory, case study research, historical research, narrative inquiry and action research (Creswell, 2014; Saunders, Lewis and Thornhill, 2016). Table 8.2 provides a concise description of each alternative and a brief justification for its misalignment and unsuitability as a potential research strategy, given the aims of this particular empirical study. This further supports the suitability of the selected survey strategy, and more specifically the interview survey strategy, as most applicable to this evaluation study.

*Table 8. 2: Alternative Research Strategies and Justifications for Unsuitability [Source: Researcher's own construction, adapted from Creswell (2014) and Saunders, Lewis and Thornhill (2016)]*

| Alternative Research Strategy | Brief Description | Justification for Unsuitability |
|---|---|---|
| **Ethnography** | Aims to gain a deep understanding of an intact group's values, culture, language, behavioural patterns and living environment by observing and participating in the natural setting for a prolonged period of time. | The study does not aim to gain an understanding of participants' values, culture, behavioural patterns or living environment in their natural settings. |
| **Grounded Theory** | An iterative inquiry design that aims to inductively build abstract and naturalistic theory of a process, action or interaction that is grounded in the views, perceptions, sensemaking and meaning-makings of participants. | The study does not aim to inductively build abstract and naturalistic theory. The proposed framework is not solely grounded in participants' views, perceptions or meaning-makings, but is strongly grounded in theory. |

| | | |
|---|---|---|
| **Case Study** | Aims to develop an in-depth, detailed, rich and contextual understanding of a specific real life case (or a small handful of specific real life cases) bound by time, location, event, process, group or activity. | The study is not focused on gaining an in-depth and detailed contextual understanding of a specific real life case (or a small handful of specific cases), nor is the study bound by a particular location, event or group. |
| **Historical** | Aims to critically inquire about, describe, explain and interpret past events by studying the oral histories, text and document records, and visual accounts (such as photographs) of those historical events. | The study does not aim to describe, explain or interpret past events, nor does it aim to examine oral histories, text/document records or visual accounts of historical events. |
| **Narrative Inquiry** | Aims to produce a chronological "thick description" of people's experience, interpretation, sensemaking and meaning-making of contextual events and social relations through narrative storytelling. | The study does not aim to gain a deep understanding of peoples' experiences regarding social relations or contextual events; narrative storytelling is not relevant to the study. |
| **Action Research** | An iterative, emergent and collaborative process of inquiry designed to promote learning, empower participants and provide solutions to problems by bringing about meaningful intervention change in problem-settings. | The study does not aim to engage in an iterative and collaborative inquiry process. The study does not aim to deliver practical change interventions to real world problem settings. |

A survey strategy offers several advantages. Firstly, survey interviews provide a valuable vehicle for measuring a variety of unobservable data, such as the tacit and implicit knowledge, thoughts and experience possessed by knowledgeable and experienced subject matter expert researchers and practitioners in the area of mHealth physical activity app design, development and evaluation (Bhattacherjee, 2012). Secondly, surveys (both categories) provide an ideal means of collecting data about a group of individuals that is too large to observe or approach directly (Bhattacherjee, 2012). Knowledgeable and experienced researchers and practitioners in the mHealth physical activity app design arena are not bound by location, time or context, and are located all over the world, which makes their accessing challenging and impractical. Moreover, considering that this evaluation study is conducted amidst the coronavirus (COVID-19) global pandemic and countrywide lockdown, direct access to participants, even on a local and national level, is unworkable. Thirdly, the unobtrusive nature of the survey strategy has shown to be a preferred approach by participants, particularly considering that their natural settings and contexts are not encroached upon or intervened (Bhattacherjee, 2012). This unobtrusive and less threatening approach can make participants feel more comfortable with sharing the true nature of their perceptions and thoughts regarding mHealth physical activity app design. Fourthly, surveys (both categories) provide a helpful means of reaching certain groups of individuals (which, in this case, are mHealth physical activity app researchers and industry practitioners) within given time, resource and travel constraints (Bhattacherjee, 2012). Lastly, surveys (both categories) afford an economical method in terms of researcher and research project time, effort and cost (Bhattacherjee, 2012).

Despite these several advantages, it is important that the researcher be aware of the disadvantages of the survey research strategy. The most notable of which relates to biases. Surveys (both categories) may be subject to respondent bias if the participant selected does not possess adequate knowledgeable expertise or experience or if they have a biased opinion regarding the phenomenon of interest (Bhattacherjee, 2012). Non-response bias describes when participants who fail to respond to or participate in a survey would provide different and meaningful insights than those who do respond and participate (Bhattacherjee, 2012). Response rates can be improved by employing several strategies: advanced notification and confirmation; providing a clear statement on the purpose and importance of the study; incentives; building trust and rapport; and assuring confidentiality, anonymity and privacy (Bryman, 2012). Sampling bias occurs if the sampled participants had a more likely chance of being selected to participate in the study (Bryman, 2012). Although generally present in non-random samples, sampling bias can also be present in some random samples (Bryman, 2012). Social desirability bias occurs if participants respond to questions in ways that portray themselves in a socially desirable or acceptable manner as to avoid embarrassment or negative perceptions about themselves or others, rather than providing honest and truthful responses (Bryman, 2012). Although social desirability bias cannot be overcome in questionnaires, social desirability bias and inconsistencies in responses can be spotted by an interviewer, and gently probed or enquired about in interview settings (Bryman, 2012). Another bias to be aware of is recall bias. Recall bias occurs when participants are systematically more or less likely to provide inaccurate and/or incomplete information regarding past events and experiences (Bhattacherjee, 2012). In an interview setting, recall bias can be mitigated if an interviewer makes an effort to anchor a participant's memory in specific events as they happened (Bhattacherjee, 2012). Considering that the nature of this empirical study requires participants to access current knowledge, skills, experience and memory, and does not rely solely on their meticulous recalling of specific past events, this bias is largely overcome.

Overall, the interview survey strategy adopted in this study is compatible and appropriate for use with the DSRM, the interpretivist paradigm, and the qualitative linguistic interpretivist approach employed for evaluating the proposed Interdisciplinary mHealth App Design Framework (conceptual meta-model artefact). The qualitative interview survey strategy provides opportunity for non-random, purposeful and small sampling (Merriam, 1998; Mohajan, 2018), and allows for semi-structured interviews as a method to ascertain rich

contextual data regarding the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps.

## 8.4 Qualitative Interview Data Collection Design

Interviews are employed as the data collection method for gathering qualitative primary data on the actors, objects (artefacts), knowledge practices and processes (and activities) relevant to the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps. A research interview is a purposeful conversation between two or more persons, in which an interviewer (researcher) asks an interviewee (participant) a series of concise and unambiguous questions (Saunders, Lewis and Thornhill, 2016). The participant's responses are captured through note-taking and/or electronic device recording (Saunders, Lewis and Thornhill, 2016). Interviews can be approached from different philosophical paradigms, with interpretivism generally being the most adopted perspective (Gubrium, et al., 2012). An interpretivist perspective regards an interview as a subjective and socially constructed data collection method (Gubrium, et al., 2012). An interview is co-produced on the one hand by the interviewee, who shares their subjective views and interpretations through their responses, and on the other hand, by the interviewer, who asks the questions, responds to the interviewee's queries and answers, and uses interpretive sense-making and meaning-making to analyse the transcribed interview data (Gubrium, et al., 2012). In accordance with the interpretivist and linguistic interpretivist paradigmatic assumptions and views discussed in Section 8.2, this study adopts an interpretivist approach to the interviewing process.

In interpretive and qualitative interviews, the interviewer (researcher) is considered an important part of the measurement instrument; that is, the interviewer/researcher is a human instrument (Tuckett, 2005; Seidman, 2006). The interviewer has a responsibility to clarify any questions or concerns raised by interviewees during the interview process, and must make a proactive effort to not artificially bias or influence interviewees' responses (Bhattacherjee, 2012). The interviewer generally takes the lead position in guiding the interview process towards accomplishing the goal(s) set out in the interview design, and the professional relationship formed between the interviewer and interviewee is key to the success of the interview process (Seidman, 2006). Establishing trust and rapport with the interviewee is also important for ensuring the collection of quality, relevant and useful data (Seidman, 2006).

Interpretivistic and qualitative interviews are deemed a reliable and valid data collection method in DSR, and are particularly valuable for evaluating the social and socio-technical aspects of artefacts, rather than the purely technical aspects of artefacts (Hevner and Chatterjee, 2010). A number of masters and doctoral DSR studies have utilised different types of interviews, such as semi-structured interviews, to conduct ex-post evaluations on proposed DSR artefacts (Pries-Heje, Baskerville and Venable, 2008); for example, Koppenhagen (2013), Lupanda (2018) and Francisco and da Costa Zanela Klein (2020).

While there is no standardised format for guiding the design and conduct of research interviews, interview guidelines and ethical principles should be observed to yield trustworthy and authentic results and findings (Lincoln and Guba, 1985; Gubrium, et al., 2012). The evaluation design comprises the following components that guide the Interdisciplinary mHealth App Design Framework investigation: (1) *the empirical study research question*; (2) *the unit of analysis*; (3) *virtual semi-structured interviews as the research instrument*; (4) *the sampling technique and subject selection*; (5) *the virtual semi-structured interview questions*; (6) *virtual interview guidelines*; and (7) *the virtual semi-structured interview materials*.

### 8.4.1 Empirical Study Research Question and Objective

The empirical study research objective aims to evaluate, revise and enhance the quality of the Interdisciplinary mHealth App Design Framework by exploring and investigating its components and subcomponents in the context of the mHealth physical activity (promotion) behaviour change intervention app application domain environment (Hevner, 2007). The following research question guides the empirical interview evaluation study:

- *What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?*

The answer to this fourth research sub-question also indirectly contributes to answering the third research sub-question (outlined in Chapter 1), which asks: *"How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*. As discussed in Subsection 8.2.2.1, the quality of the Interdisciplinary mHealth App Design Framework is evaluated against three evaluation criteria: (1) *construction adequacy*; (2) *language adequacy*; and (3)

*clarity* (Schütte and Rotthowe, 1998). These three criteria inform the lens through which the key primary data based empirical insights are drawn, and frame how the quality of the proposed framework is improved through circumscription in a DSR evaluation cycle (illustrated in Figure 8.1 in Section 8.2.1).

### 8.4.2 The Unit of Analysis

The unit of analysis is the entity or subject matter that is analysed in an empirical research study (Roller and Lavrakas, 2015). When analysing data, the unit of analysis becomes important because it provides the basis from which thematic codes can be developed by the researcher, and meaningful themes, subthemes, categories and relationships can be identified and interpreted (Roller and Lavrakas, 2015). Identifying the particular constructs of interest, if known, can further clarify the unit of analysis and thematic coding process (Roller and Lavrakas, 2015). The particular constructs of interest within this study's unit of analysis are framed by the boundary object view (the tri-composite theoretical framework) and the proposed framework (Chapter 7). Therefore, the unit of analysis constructs of interest concern the actor, boundary object and supporting artefact, knowledge sharing, and process content of the transcribed interview responses, pertaining specifically to the design, development and evaluation of mHealth physical activity behaviour change intervention apps (as the context). The unit of analysis data is analysed from the transcribed interviews and is provided by the study participants (interviewees), namely the physical activity knowledgeable and experienced researchers and industry practitioners providing the interview responses.

### 8.4.3 The Research Instrument: Virtual Semi-Structured Interviews

Semi-structured interviews are employed as the instrument for collecting qualitative primary data on the mHealth physical activity app context. Interviews are conducted virtually on a one-on-one basis, between the researcher (interviewer) and knowledgeable and experienced subject matter expert researchers and industry practitioners (interviewees) who have expertise and skills in the design, development and evaluation of mHealth physical activity behaviour change intervention apps. The one-on-one virtual semi-structured interviews are estimated to be 45 to 60 minutes in duration, depending on the descriptive and explanatory openness of participants' responses. Interviews are conducted using virtual meeting platforms of the participant's preference, of which the most popular platforms are Zoom Video Communications Inc. (shortened to Zoom) (Zoom, 2021), Google Meet (Google, 2021) and Microsoft Skype Communications S.A.R.L (Skype, 2021) (Adom, Osei and Adu-Agyem, 2020).

The online virtual conferencing technology-based approach to interviewing substitutes the traditional offline physical face-to-face interview approach for two key reasons. Firstly, in the face of the global coronavirus (COVID-19) pandemic outbreak, worldwide country lockdowns and human movement and social distancing restrictions, the use of virtual telecommunication and conferencing technologies have surged exponentially as an alternative means to conducting personal, professional and research communications (Adom, Osei and Adu-Agyem, 2020; Gray, et al., 2020; Porter and Hook, 2020). Secondly, the target participants are located in several international countries, making physical face-to-face interviews significantly costly, time-consuming, and infeasible with domestic and international travel restrictions. Virtual telecommunication platforms offer several advantages: removing logistical limitations; saving costs, time and resources (for example, video and audio recording equipment); providing secure and private data recording and storage capabilities; ensuring personal safety; screen-sharing functionality; and offering a convenient, non-intrusive, comfortable and engaging means of communicating (Gray, et al., 2020; Dodds and Hess, 2021).

The commonly reported challenges of virtual telecommunication platforms should also be noted and actively guarded against when possible. This includes: technical and internet connection set up issues; privacy and data security anxieties; technological costs (albeit outweighed by face-to-face interviewing costs); purchasing and premium membership costs with some company products and service platforms; potential for interruptions; inability to read all nonverbal and body language communication; and other digital technology challenges (for example, poor video/audio quality or unstable/delayed internet connectivity) (Archibald, et al., 2019; Gray, et al., 2020). Despite these challenges and concerns, recent studies have shown participants to favour virtual qualitative research interviews above traditional face-to-face, telephonic and email interviews, with a particular preference for Zoom over other videoconferencing services, platforms and products (Archibald, et al., 2019; Gray, et al., 2020; Dodds and Hess, 2021). The interviewer (researcher) assumes responsibility for addressing challenges where possible, for instance, reassuring the ethical privacy, anonymity and confidentiality of recorded data (Dodds and Hess, 2021).

The degree of interview structure, and hence the selected type of interview, needs to be appropriate for answering the evaluation study research question (Gillham, 2000). Interview structure can range from unstructured to structured along a continuum (Gillham, 2000). Semi-structured interviews lie at the midpoint between these two extreme verbal data collection

dimensions, where the style of interview is more structured than purely open-ended interviews, but is less structured than questionnaires, providing a flexible blend of open and closed questions (Gillham, 2000). This flexibility allows the researcher to retain an adequate structure to address specific dimensions of their research questions with each interviewee, while simultaneously allowing space for participants (interviewees) to offer new contributions and alternative perspective insights and meanings that enrich the researcher's contextual understanding of the topic of study (Galletta, 2013). Flexibility also provides the researcher with an opportunity to gain further clarification and explanation to responses made, particularly with regard to nuanced and interpretively flexible concepts and constructs (Galletta, 2013).

Semi-structured interviews are a valuable data collection tool to use when the researcher is knowledgeable enough about a topic or phenomenon to identify the domain (that is, they know the boundaries of the topic and what is and is not pertinent to ask in relation to the empirical study research question), but they are not knowledgeable enough to anticipate the participants' responses (Gubrium, et al., 2012). This quality further demonstrates the appropriateness of semi-structured interviews for this specific evaluation study, in which the researcher possesses adequate knowledge on the topic of investigation (obtained over several years, demonstrated throughout Chapters 1 to 7 and in the associated Appendices), but is not able to anticipate all possible respondent answers in terms of the mHealth physical activity app context per se.

In addition, semi-structured interviews are useful for conducting exploratory research, which is the case with this study (Galletta, 2013). Employing semi-structured interviews as a research instrument aids in gaining a deeper contextual and more holistic interdisciplinary understanding from knowledgeable and experienced subject matter expert researchers and industry practitioners on how the collaborative design, development and evaluation process of mHealth physical activity behaviour change intervention consumer apps can be improved. Galleta (2013) describes a key benefit of semi-structured interviews as being both attentive to participants' contextual and experienced-based knowledge and understanding, while also addressing theoretically driven variables of interest, which in this study, are informed by the tri-composite theoretical framework (the boundary object view) and the elemental statements (and terms) of the proposed conceptual meta-model (proposed conceptual framework).

Semi-structured interviews are recognised as a valid and credible tool for ex-post artefact evaluation in DSR studies (Hevner and Chatterjee, 2010; Helfert, Donnellan and Ostrowski, 2012; Gerber, Kotze and van der Merwe and, 2015), and have been employed as a reliable data

collection research instrument for evaluating artefacts in doctoral DSR projects and other DSR studies (for example, Koppenhagen (2013), Lupanda (2018) and Francisco and da Costa Zanela Klein (2020)). Employing one-on-one semi-structured interviews as a data collection instrument is also appropriate for use with the qualitative DSR linguistic interpretivist approach and interpersonal verification procedure discussed in Subsection 8.2.2 (Table 8.1), where the proposed conceptual meta-model's statements and domain-language-based ontology are (re)constructed, confirmed and validated with member representatives of the mHealth physical activity app linguistic community (Becker and Niehaves, 2007; Becker, Niehaves and Pfeiffer, 2008a).

### 8.4.4 Sampling Technique and Subject Selection

The mHealth physical activity behaviour change intervention app linguistic community member representatives (interview participants) are recruited using the snowball sampling technique. Snowball sampling is a type of non-probability, purposive and convenience sampling technique that starts by identifying a few respondents who match the criteria for inclusion in the study, and then asks those respondents to recommend others they know who also meet the same selection criteria (Bhattacherjee, 2012). Also referred to as the chain method or chain referral, this technique is generally used in qualitative research studies and is useful to employ in situations where there is no sampling frame for the population and when it is difficult to access subjects with the target characteristics (Naderifar, Goli and Ghaljaie, 2017).

In this study, a selection of potential participants – who meet the criteria as knowledgeable and experienced subject matter expert researchers and industry practitioners in the multi- and interdisciplinary field of mHealth physical activity app design, development and evaluation – are first contacted via email. Those who respond, whether or not willing to voluntarily participate in the study, are asked to recommend additional future participants who may be deemed suitable. Not all recommended subjects will necessarily be selected as participants; the subjects' personal involvement in the mHealth physical activity app design process, and their degree of knowledge, expertise and experience influences whether they are selected by the researcher. Participants may have experience in academia, research and/or industry/commercial practice, but must have experience as a collaborating team member on one or more multi- and/or interdisciplinary mHealth physical activity behaviour change intervention app projects. Participants may have experience in commercial and/or research consumer apps. To clarify, commercial consumer apps are published publicly on the

commercial app market (such as the Google Play and Apple App Stores), whereas consumer research apps are designed, developed and evaluated specifically for research purposes (for example, during a masters or doctoral project) and are not officially released to the public. The characteristics of the full participant sample is unclear at the onset of the semi-structured interview process, and only becomes clear once the data gathering process is complete. Table 8.3 provides a summary overview of the participant inclusion criteria.

*Table 8. 3: Participant Inclusion Criteria [Source: Researcher's own construction]*

| Criteria | Inclusion Requirements |
|---|---|
| **Experience** | Experience, knowledge, skills and expertise as an expert, researcher, academic, and/or commercial industry practitioner on multi- or interdisciplinary projects for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps. |
| **Areas of Expertise** | Participants can hold knowledge and experience in one or more of the following fields and areas of expertise: Information Systems; User Experience Design; User Interface Design; Health Psychology; Health Sciences; Health Behavioural Change Intervention Sciences; Persuasive Systems Design; Game Design and Development; Computer Sciences; DevOps; Mobile Application Design and Development; Business and Project Management; Product Management and Design; Exercise Sciences; Sport Sciences; Physiology; Fitness/Personal Training; and Physical Activity. |
| **Duration of Experience** | Minimum of two years experience as a collaborating team member on multi- and/or interdisciplinary mHealth physical activity behaviour change intervention app projects. |
| **Form of Experience** | Experience can be in the form of research, academic or commercial industry practice involvement, or a combination thereof. |
| **Age** | 24+ years of age. |
| **Gender** | Non-discriminatory. Participants can identify with any gender identity. |
| **Race and Culture** | Non-discriminatory. Participants can be of any race, ethnicity and culture. |
| **Geographical Positioning** | International. |
| **Language** | English. Participants need not be first-language or native English speakers, but English fluency and proficiency is imperative. |
| **Health Status** | Participants are required to be sufficiently healthy to participate. |

The semi-structured interview process ceases when data saturation is reached, in which case the interviewer begins to hear the same information in interviewees' responses and no longer learns anything new (Seidman, 2006). Although, the longer a researcher examines more data, it is likely that new things will continue to emerge, to which Strauss and Corbin (1998, p.136) rather describe the point of saturation as a "matter of degree", where it becomes "counter-productive" to continue the interview process since anything "new" uncovered does not contribute meaningfully to the overall evaluation of the proposed theory and framework.

The predicted number of participants at point of saturation is debated (Mason, 2010; Vasileiou, et al., 2018). Some researchers estimate between 20 and 30 subjects for qualitative interviews (Vasileiou, et al., 2018), while others argue that it is impossible to estimate how many subjects from the onset, explaining that the interviewer will instead only know when "enough" participants have been interviewed once having gone through interactive reflection at every step of the interview process (Seidman, 2006, p.55). Seidman (2006) points out that while saturation is a useful measure of knowing when to stop the interview process, the practical constraints of time, money and other resources frequently play an important role in doctoral research studies. Seidman (2006, p.55), however, does suggest that doctoral students "err on the side of more rather than less", yet cautions that sizeably more participants does not necessarily result in richer data results. Seidman's (2006) notions are echoed by Mason (2010) who conducted a study on the sample sizes and saturation points of doctoral studies using qualitative interviews as a data collection method. Of 560 analysed doctoral studies, Mason (2010) found the median and mean sample size to be 28 and 31, respectively, and the most common sample sizes to be 20 and 30, followed by 40, 10 and 25. For purposes of this evaluation study, a preliminary estimation for the semi-structured interview sample size is set between 25 and 30 participants, with a maximum threshold of 32; although this is open to change depending on the point at which saturation is achieved.

Snowball sampling holds advantages as an efficiently simple, exploratory, cost effective and timesaving method to reach subject participants who are difficult to access using other sampling methods (Naderifar, Goli and Ghaljaie, 2017). The disadvantages of this technique relate to the researcher's minimal control over the chain referral, the potential for sampling bias (subject tend to recommend people they know well, potentially affecting sample diversity), and the sample's representativeness in that the findings cannot be generalised to the population (in comparison to quantitative large-scale random representative samples) (Naderifar, Goli and Ghaljaie, 2017). While the researcher cannot overcome these disadvantages entirely, effort is put forward to actively seek diversity in subjects (by selecting participants with various positions and degrees of experience from different backgrounds) as well as attempts to reduce the potential for sampling bias.

### 8.4.5 Virtual Semi-Structured Interview Questions

The virtual semi-structured interview questions are designed to help the researcher gain a deeper and clearer understanding of the actors, objects (boundary objects and supporting

artefacts), knowledge sharing practices and processes (and activities) commonly used in the design, development and evaluation of mHealth behaviour change intervention consumer apps in the physical activity context. Considering the comprehensiveness and extensive detail of the proposed conceptual meta-model (framework artefact) evident in Chapter 7, questions are designed specifically to explore and investigate components and subcomponents pertinent to the mHealth physical activity app context on a relatively middle-to-high level of abstraction. In other words, questions are orientated towards (re)constructing, confirming and interpersonally verifying the framework's main elements, rather than its intricate low-level details. For example, with regard to the "actors" component (Chapter 7, Section 7.3), questions are designed to enquire about the middle-to-high level constructs associated with direct (interdisciplinary team member) and indirect (third-party stakeholder and end-user) actors typically involved in any given mHealth physical activity intervention app project.

The low-level constructs associated with all of the bullets points listed in the proposed interdisciplinary team member and perspectives template (Chapter 7, Appendix J.2) and the proposed guideline recommendations for high-performing interdisciplinary teams (Chapter 7, Appendix J.3), for instance, will not be asked. The justification for adopting a middle-to-high, rather than a low, level approach to questioning relates largely to what can be realistically included in one interview session. Given the comprehensiveness, scale and extensive detailing of the proposed Interdisciplinary mHealth App Design Framework, it would be a time-consuming, resource-intensive and impractical task to attempt to verify every definitive detail. A focus on the quality rather than the quantity of questions provides a richer and more meaningful data set, which can offer valuable findings that address the empirical study research question (Subsection 8.4.1), meet the evaluation criteria (Subsection 8.2.2.1) and inform the iterative refinement and enhancement of a quality DSR artefact contribution (Chapter 10).

The semi-structured interview topics and questions are deductively structured and framed in accordance with the conceptual statements, themes and subthemes of the proposed Interdisciplinary mHealth App Design Framework. The interview questions are orientated towards gathering elemental statement and terminological structure information, which informs the domain language of the conceptual meta-model. However, in order to appropriately verify the conceptual and elemental statements of the framework through the interview process, an important three-sided challenge needs to be considered and addressed. This challenge concerns the nature of the tri-composite theoretical framework that has been proposed as the

novel design solution in this research project; that is, the tri-composite (community of practice, boundary object and knowledge boundary) theoretical framework which underpins and informs the Interdisciplinary mHealth App Design Framework's components, composition and terminological structure (introduced and discussed in Chapter 5).

Firstly, the researcher cannot assume the participants to be familiar with the theoretical concepts and relationships of the three (community of practice, boundary object and knowledge boundary) theories. The researcher also cannot expect the participants to become familiar with or learn about these theories for the purpose of the interviews. Secondly, the researcher cannot impose the formal theory terminology on participants, and cannot frame the interview questions using the theories technical jargon, as this would negatively impact participants' understanding of the interview questions, and as a result, would lead to inadequate answers and poor quality, valueless data. Thirdly, the imposing of theory on the participants would bias and distort the authenticity of their responses. Participants' responses should instead be contextually rich and relevant to the physical activity domain language so that the researcher's inductive thematic analyses and inferences can meaningfully contribute to the quality modification and revision of the Interdisciplinary mHealth App Design Framework. For these reasons, the interview questions are deductively structured and framed by the researcher in accordance with the conceptual and elemental statements (and terms), yet are constructed and phrased with informal, colloquial language so that participants will be able to comprehend them, regardless of their disciplinary backgrounds and whether or not they are familiar with the three theories.

In line with the reasoning behind not imposing the tri-composite theoretical framework and its technical terminology on participants, participants will also not be shown the Interdisciplinary mHealth App Design Framework (Chapter 7). On the one hand, arguments can be made that showing the framework to participants can provide an opportunity for them to voice their opinions, critiques and suggestions for its quality evaluation and revision. On the other hand, showing the framework to participants can potentially bias, limit and constrict their responses. In addition, given its comprehensiveness and extensive detailing, showing participants the framework may lead to them feeling overwhelmed or discombobulated, which would be unnecessary and fruitless for this empirical evaluation study.

The interview questions are directed towards participants' (tacit and explicit) knowledge and expertise of the objects, knowledge sharing and processual (and activity) practices applicable to the design, development and evaluation of mHealth physical activity consumer apps,

informed by their formal qualification(s), expertise, skills, and research/practice experience(s). The questions are constructed from the interview topics, which align with the themes and subthemes of the Interdisciplinary mHealth App Design Framework. Table 8.4 outlines (1) the interview topics, which align with the framework's conceptual statements, themes and subthemes, and (2) the aims of the interview questions, which through the semi-structured interview interpersonal verification process, provides insight into the elemental statements and domain-language-based ontology for evaluating and improving the proposed Interdisciplinary mHealth App Design Framework (conceptual meta-model artefact). The main interview topics cover the *"actors"*, *"process"*, *"boundary objects"*, *"supporting artefacts"*, *"knowledge"*, *"project boundary"* and *"outcomes"* for interdisciplinary and collaborative mHealth physical activity behaviour change intervention consumer app projects.

*Table 8. 4: Interview Topics and Question Aims [Source: Researcher's own construction, adapted from Chapter 7 and informed by Table 8.1]*

| **Interview Topic** | | | **Interview Question Aim** |
|---|---|---|---|
| **Conceptual meta-Model Statements (Contextualised to the mHealth Physical Activity App Domain)** | **Interdisciplinary mHealth App Design Framework** | | **Elemental Statement and Terminological Structure (Interpersonal Verification Process)** |
| | **Theme** | **Subthemes** | |
| An interdisciplinary team (stemming from heterogeneous communities of practice) collaborates, and works with third-party stakeholders and end users, to produce a mHealth physical activity behaviour change intervention consumer app. | Actors | Interdisciplinary team (team leader/project manager and boundary spanners/workers) | • Key aim: Understand and identify "who".<br>• Determine the actors in the interdisciplinary team.<br>• Determine the heterogeneous communities of practice involved in mHealth physical activity intervention consumer app projects.<br>• Identify third-party stakeholders.<br>• Determine end user involvement. |
| | | Third-party stakeholders | |
| | | End users (direct and indirect) | |
| A nine-step interdisciplinary collaborative process guides the interdisciplinary team's design, development and evaluation of a mHealth physical activity behaviour change intervention consumer app. | Process | Interdisciplinary | • Key aim: Determine and understand "how".<br>• Determine the process nature and behaviour.<br>• Identify, label and understand the steps and activities of the process for designing, developing and evaluating mHealth physical activity intervention consumer apps (i.e. understand how the team carries out the process). |
| | | Collaborative | |
| | | Nature (structure, agile behaviour and quality) | |
| | | Steps (9) | |
| An interdisciplinary team employs, refers to and (re)creates boundary objects to guide, support, facilitate and mediate the heteropraxial design, development and evaluation activities and knowledge practices during the interdisciplinary collaborative process. | Boundary Objects | Primary | • Key aim: Determine and identify "what".<br>• Determine and identify the objects commonly used, referred to and created by the team to design, develop and evaluate mHealth physical activity intervention consumer apps.<br>• Determine the names of specific object software and tools used during the process. |
| | | Secondary | |
| | | Tertiary | |
| | | Design | |
| | | General | |
| An interdisciplinary team uses, refers to and adapts supporting | Supporting Artefacts | Methods | • Key aim: Determine and identify "what". |

| | | | |
|---|---|---|---|
| artefacts to guide, support and facilitate the heteropraxial design, development and evaluation activities and knowledge practices during the interdisciplinary collaborative process. | | Standards, guidelines and codes of practice<br>Other and materials | • Determine the supporting artefacts commonly used and referred to by the team to design, develop and evaluate mHealth physical activity behaviour change intervention consumer apps.<br>• Determine the names of specific methods, standards, guidelines and codes of practice. |
| An interdisciplinary team employs, refers to and (re)creates knowledge artefacts to facilitate, mediate and develop common language, meanings, interests and shared understandings across knowledge boundaries during the interdisciplinary collaborative process. | Knowledge | Syntactic (transfer, exchange)<br>Semantic (translate, deliberate)<br>Pragmatic (transform, negotiate)<br>Shared understanding (shared mental models, common ground)<br>Dynamics | • Key aim: Determine and understand "how" and "what".<br>• Determine how the team overcomes knowledge boundaries and challenges.<br>• Understand how the team creates shared understanding.<br>• Identify what knowledge artefacts are used and/or created to overcome knowledge boundaries and create shared understanding. |
| Within a project boundary, an interdisciplinary team engages in object-supported and knowledge sharing practices during the interdisciplinary collaboarative process. | Project Boundary | Structure<br>Scope | • Key aim: Determine and understand the "what".<br>• Determine and understand the general structure and scope of mHealth physical activity behaviour change intervention consumer app projects. |
| An interdisciplinary collaborative process and product results from the team carrying out a given project. | Outcomes | Process<br>Product | • Key aim: Determine and understand the "what".<br>• Determine and understand the main outcomes resulting from mHealth physical activity intervention consumer app projects. |
| Not part of the conceptual meta-model. | Challenges and improvements | | • Key aim: Determine "what" and "how".<br>• Determine what the key challenges are and what requires future improvement in the emerging interdisciplinary mHealth app arena. |

All participants are asked the same set of questions, although depending on how each semi-structured interview unfolds, the sequential ordering and nature of the questions may vary and are likely to be customised to align with the open-ended responses of each participant. Additional (planned and/or impromptu) prompts and probes may be used in instances where the interviewer (researcher) wishes to clarify any ambiguities or further explore responses provided by interviewees (Gubrium, et al., 2012; Galletta, 2013). Prompts are used to clarify or explain questions, or used to remind the interviewee about something you would like them to answer or cover (Gillham, 2000). Probes are supplementary and investigatory follow-up questions or responses that aim to get the interviewee to expand more on a particular topic of discussion, so that richer and more detailed information can be gathered (Gillham, 2000). Probes can be used for confirmatory, clarification or explanatory purposes (Gillham, 2000).

According to Gubrium, et al. (2012, p. 82), in research semi-structured interviews, "probes may test respondents' interpretations of terminology", which is useful for determining and

understanding the domain language relevant to mHealth physical activity behaviour change intervention consumer app design, development and evaluation. Probing questions can be framed around what, why, how, where, who and when questions (Gillham, 2000). Probing techniques can include echoing; silence; verbal agreement; asking an interviewee to "tell me more"; asking for examples; and asking for specific experiences (Whiting, 2008). Towards the end of the interview session, participants have the opportunity to make suggestions, additional comments or provide cautionary pointers regarding the themes and subthemes covered during the interview, which can further enrich the iterative improvement and refinement of the Interdisciplinary mHealth App Design Framework.

### 8.4.6 Virtual Semi-Structured Interview Guidelines

Best practice guidelines are referenced for conducting professional virtual semi-structured research interviews during the primary data collection process. Establishing professional relationship trust, confidence and rapport with interview respondents is essential for eliciting rich and valuable data (Seidman, 2006). Efforts made to create a comfortable, friendly, safe and engaging virtual atmosphere helps ease the interview conversations, allowing interviewees to securely disclose and share meaningful responses that can contribute to the quality of the artefact's evaluation and subsequent revision (Gubrium, et al., 2012; Saunders, Lewis and Thornhill, 2016). Table 8.5 provides eleven best practice guidelines for conducting virtual research interviews; an adapted guide compiled from published works (Whiting, 2008; Gray, et al., 2020; Huppert and Babik, 2020; Dodds and Hess, 2021).

*Table 8. 5: Virtual Semi-Structured Research Interview Guidelines [Source: Adapted from Whiting (2008), Gray, et al., (2020), Huppert and Babik (2020) and Dodds and Hess (2021)]*

| Guideline | Description |
|---|---|
| **1. Test Technology, Internet Connection and Virtual Platform Tool** | • Check that the computer, audio and camera equipment is functioning properly. Test the microphone, camera and audio headset.<br>• Ensure a strong and stable internet connection.<br>• Test the recording feature on the virtual platform.<br>• Ensure virtual platform software is registered with, downloaded and up-to-date. Complete the profile with a professional name and photograph, and run an audiovisual test on the virtual platform. |
| **2. Interviewee Technology Support** | • Enquire about the interviewee's familiarity, comfort and confidence with using virtual videoconferencing technology and the virtual platform software of choice well in advance of the interview meeting.<br>• If the interviewee exhibits inexperience and dis-ease, provide helpful information tips to support their using the technology for the duration of the interview.<br>• Prior to the interview, request interviewees to check that their computer, audio and camera equipment is functioning properly, and to test their microphone, camera and audio headset.<br>• Request interviewees to inform the interviewer of any technological or virtual platform challenges in advance. |

| | |
|---|---|
| **3. Choose an Optimal Environment** | • Choose a private and enclosed space at home or at the university institution's campus to conduct the interview. Ensure the surroundings are tidy and presentable in the video background, or use a professional virtual screen background. Optimise lighting in the room.<br>• Position the camera at face level so that the angle is most natural. |
| **4. Avoid and Plan for Distractions** | • Interviewer ensure that their virtual environment setup is distraction free. Switch personal digital technology on silent. Close windows to reduce noise.<br>• Account for interview time taken up by possible distractions and noises from the interviewee (for example, family members, pets or incoming calls). |
| **5. Provide a Direct Link to Interview Meeting** | • Once a scheduled interview meeting time is agreed upon by both parties, provide interviewees with an invitation and direct link to the live interview meeting (via Google email calendar invitation).<br>• Provide interviewee's with a professional and gentle reminder prior to the interview meeting. |
| **6. Storage Capacity** | • Before starting the interview process, the researcher needs to plan for the computer data or cloud storage required to save the interview recordings.<br>• Create and save a secure backup of the interview recordings if necessary (via cloud storage or external hard drive). |
| **7. Prepare Interview Questions in Advance** | • Prepare and review the semi-structured interview questions and planned probes in advance. Review the interview objectives and data intended to be gathered during the interview.<br>• Before commencing the interview process, perform a mock virtual interview with a peer, mentor or supervisor using the virtual platform software. Get feedback on the content of the interview questions, answers and eye contact/body language.<br>• Practice asking interview questions and planned probes. |
| **8. Conducting the Interview Meeting** | • On the day(s) of the scheduled interview, recheck and retest technology, internet connection and virtual platform tool (Guideline 1). Close software programs that may prompt alert messages or notifications. Make an effort to avoid potential distractions (Guideline 4).<br>• Dress professionally and presentable.<br>• Make eye contact with the camera rather than the computer screen, as you would in an in-person interview. Avoid fidgeting or swivelling in chair.<br>• Present with a friendly, engaging, unbiased, empathetic and conversational demeanour. Be attentive and demonstrate active listening.<br>• Ask legitimate questions clearly and intelligently, and provide interviewees with an opportunity to clarify questions if needed.<br>• Responses to an interviewee's answers must be professional and unbiased. Do not exhibit surprise or disapproval of any answers as this discourages openness and disclosure.<br>• Ensure the interview remains on track within the allocated timeframe and that there is adequate time to ask and answer all interview questions. |
| **9. Managing the Consent Process** | • Provide interviewees with an informed consent form well in advance of the interview meeting. Request that interviewees sign and return the informed consent form before the scheduled interview meeting. Allow for digital signatures if manual signing and scanning is not possible.<br>• Before starting the interview, review the study's purpose and the consent form (even if already signed and returned). Confirm that the participant has reviewed the information sheet.<br>• When starting the interview, review the informed consent form, assure interviewees of anonymity, privacy and confidentiality, and invite questions as to ensure participants understand and are comfortable with the interview process. Record the interviewee's verbal consent (consent for both the interview and audiovisual recording) prior to asking the interview questions. |
| **10. Closing the Interview** | • Provide interviewees with the opportunity to ask questions or provide comments at the end of the interview.<br>• Thank the interviewees for their time and input. Reassure participants that their anonymity, privacy and confidentiality will be respected, and that the recorded and stored audiovisual recordings will solely be used for the purposes of the research study.<br>• Confirm whether participants would like a copy of the summary report findings once the interview data is analysed.<br>• Post-interview, keep lines of communication open with participants. |

### 8.4.7 Virtual Semi-Structured Interview Materials

The virtual semi-structured interviews are conducted using an internationally accessible videoconferencing service platform, Zoom Video Communications Inc. (referred to in short as Zoom) (Zoom, 2021). Zoom has been reported in literature as a preferred qualitative research

platform of choice (Archibald, et al., 2019; Gray, et al., 2020). All interviews are recorded using the built-in Zoom recording functionality. Recorded interviews are downloaded and stored securely (with passwords) on the researcher's Proline desktop computer. Recordings are backed up to a personal external hard drive. For audiovisual communication, a Logitech camera, microphone and set of headphones is used during the interview. Pens and paper are also utilised by the researcher as manual notetaking tools during the interview sessions.

## 8.5 Data Collection

The virtual semi-structured interviews provide a primary source of empirical data for the research project. The DSR approach driving the research study requires that a constructed artefact (that is, the proposed coneptual framework) be evaluated in relation to an application domain/context to assess and determine its quality and validation (Hevner and Chaterjee, 2010; Venable, Pries-Heje and Baskerville, 2016). The data collection process aims to gather information particularised to the mHealth physical activity app domain/context. Virtual semi-structured interviews with knowledgeable and experienced expert researchers and industry practitioners in the mHealth physical activity behaviour change intervention app design, development and evaluation arena confirms the construction adequacy, language adequacy and clarity of the conceptual framework (outlined in Subsection 8.2.2.1), and provides insight into any relevant mHealth physical activity app context-specific gaps that require addressing in the conceptual meta-model. The primary objective for data collection is to represent the subjective viewpoint of expert researchers and industry practitioners who have experience and expertise in the area of mHealth physical activity behaviour change intervention app design, development and evaluation, particularly with regard to the actors, objects (artefacts), collaborative process and knowledge sharing activities. An analysis and reflection of the data collected through the virtual semi-structured process (Chapter 9) informs a cyclical refinement, modification and enhancement of the revised Interdisciplinary mHealth App Design Framework (Chapter 10).

## 8.6 Data Analysis

A thematic analysis method is employed to analyse the primary data collected through the virtual semi-structured interviews. The thematic analysis is performed after all of the interviews have been transcribed. The transcription process is performed by the researcher using Otter.ai Pro software. While the process of transcribing is a "time-consuming, frustrating, and at times

boring" task, it functions as a vital step in data analysis within a qualitative methodology and is an "excellent way" for a researcher to start familiarising themselves with the data (Braun and Clarke, 2006, p.17). The thematic analysis follows a six-step process.

### 8.6.1 Thematic Analysis

A qualitative thematic analysis method, incorporating a hybrid deductive and inductive cognitive reasoning strategy, is employed to analyse, make sense of and interpret the primary data collected through the virtual semi-structured interviews (Braun and Clarke, 2006; Fereday and Muir-Cochrane, 2006; Braun and Clarke, 2012; 2019; Xu and Zammit, 2020). Thematic analysis is an interpretivist and methodologically sound way of identifying, analysing and reporting codes, themes and patterns within qualitative data (Braun and Clarke, 2006; 2012; 2019). The hybrid thematic analysis incorporates both deductive (closed) and inductive (open) coding and theme analysis (Fereday and Muir-Cochrane, 2006). While the data-driven inductive approach allows for codes and themes to emerge from the transcribed data (Boyatzis, 1998; Fereday and Muir-Cochrane, 2006), the theory-driven deductive approach informs a priori template of codes and themes that align with the proposed framework (Crabtree and Miller, 1992; Fereday and Muir-Cochrane, 2006). This hybrid approach complements the empirical study research question by allowing the elements of the framework to be integral to the deductive thematic analysis while allowing new themes to emerge directly from the data through inductive coding (Fereday and Muir-Cochrane, 2006). The integration of deductive (closed) and inductive (open) coding demonstrates the flexibility of the thematic analysis method (Braun and Clarke, 2006; 2012; 2019) and results in a comprehensive and balanced view of the data (Xu and Zammit, 2020).

The thematic analysis follows a linear, systematic procedure (Braun and Clarke, 2006; 2012), but assumes an iterative and reflexive process in practice (Fereday and Muir-Cochrane, 2006; Braun and Clarke, 2019). This interactivity applied throughout the qualitative inquiry process demonstrates rigour, and is described by Fereday and Muir-Cochrane (2006, p. 4) as the overarching principle of "goodness". Creating a codebook can be helpful for deductively and inductively analysing the transcribed data, and the coding process proceeds as "a critical link between data collection and interpretation of meaning" (Nowell, et al., 2017; Xu and Zammit, 2020, p.2). The deductive (closed) coding is informed by a priori established code framework, informed by the main themes in the proposed framework (conceptual meta-model) (outlined in

Table 8.4). New emerging inductive (open) codes are add to the codes in the codebook as the coding and thematic analysis process progresses.

The thematic analysis follows the six-step process proposed by Braun and Clarke (2006; 2012): *(1) become familiar with the data*; *(2) generate initial codes*; *(3) search for themes and subthemes*; *(4) review themes and subthemes*; *(5) define and name themes and subthemes*; and *(6) produce the report*. These six steps and their descriptions are summarised in Table 8.6.

*Table 8. 6: Thematic Analysis Process [Source: Adapted from Braun and Clarke (2006; 2012)]*

| Guideline | Description |
|---|---|
| **1. Become Familiar with the Data** | • Start to become familiar with the whole data set by transcribing all of the audio recordings from the virtual semi-structured interviews.<br>• Actively read and re-read all of the semi-structured interview transcripts.<br>• Take notes on initial ideas regarding the actors, objects (artefacts) employed and the knowledge sharing and process (and activity) practices relevant to the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps. |
| **2. Generate Initial Codes** | • Code features in the data that are interesting and meaningful across all of the interview transcripts.<br>• Organise data into meaningful groups and group relevant data to each code.<br>• Codes are both theory-driven (deductive; closed) and data-driven (inductive; open). |
| **3. Search for Themes and Subthemes** | • Using interpretive analysis, create draft brief descriptions of codes to play around with organising them into theme-piles and sort the codes into potential themes and subthemes.<br>• Start thinking about relationships between codes, themes and subthemes.<br>• Collate all relevant data and interview extracts related to each potential theme and subtheme.<br>• Start creating a draft thematic map with the candidate themes and subthemes. |
| **4. Review Themes and Subthemes** | • Review whether the candidate themes and subthemes appear to form a coherent pattern with the coded data extracts (level 1) and whether they relate to the entire data set (level 2).<br>• Separate, rearrange, discard and create new themes and subthemes where necessary. In relation to each theme and subtheme, rearrange and discard data extracts where necessary.<br>• Apply principles of internal homogeneity and external heterogeneity.<br>• Create a thematic map providing a conceptualisation of the themes, subthemes and relationship patterns. |
| **5. Define and Name Themes and Subthemes** | • Refine concise and clear names, definitions and details for each theme and subtheme. In refining the specifics of each theme, categorise the findings according to themes and subthemes and the conceptual and elemental statements of the Interdisciplinary mHealth App Design Framework.<br>• Apply principles of internal homogeneity and external heterogeneity.<br>• Refine the essence of the broader story of the interpreted data in relation to the empirical study question.<br>• Specify actor, object (artefact), knowledge sharing and process (and activity) themes, subthemes and thematic relationships that are specifically relevant to guiding the design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps. |
| **6. Produce the Report** | • Analytic and argumentative narrative: Write up the thematic analysis findings as an interpreted and meaningful story about the data. Use appropriate data extracts to evidence themes, subthemes and thematic relationships.<br>• Relate the analysis and analytic narrative back to the key Interdisciplinary mHealth App Design Framework themes and subthemes (Chapters 6 and 7) and the empirical study question. |

Table 8.7 provides a fifteen-point checklist proposed by Braun and Clarke (2006) to guarantee that a good quality thematic analysis is performed in this empirical research study.

*Table 8. 7: Checklist for a Good Thematic Analysis [Source: Informed by Braun and Clarke (2006)]*

| Process | No. | Checklist Criteria |
|---|---|---|
| **Transcription** | 1. | Virtual semi-structured interviews are transcribed verbatim from the audio recordings, using Otter.ai Pro software. The transcripts are double-checked while listening to the recordings to confirm accuracy. |
| **Coding and Themes** | 2. | Each data item is given equal attention in the coding process. |
| | 3. | The coding process is comprehensive, thorough and inclusive. Themes and subthemes have not been generated using an anecdotal approach with a few vivid examples. |
| | 4. | All relevant data extracts for each theme and subtheme have been sorted and collated. |
| | 5. | Themes and subthemes have been checked against each other and in relation to the entire data set. |
| | 6. | Themes and subthemes are internally coherent, consistent and distinctive (internal homogeneity and external heterogeneity). |
| **Analysis** | 7. | Data has been analysed, made sense of and interpreted in a meaningful way. Data is not simply described or paraphrased. |
| | 8. | The data and analysis correspond. Data extracts evidence the analytic claims. |
| | 9. | Analysis conveys a well-formulated and convincing story about the data and study topic. |
| | 10. | A good balance is maintained between the analytic narrative and the data extracts. |
| **Overall** | 11. | Adequate time has been allocated to complete all steps of the thematic analysis process thoroughly. |
| **Written Report** | 12. | Details pertaining to the thematic analysis are clearly outlined and described. |
| | 13. | A good fit can be recognised between the claimed and actual thematic analysis process. The described method and written up analysis are consistent. |
| | 14. | The language and concepts used in the written up report are consistent with the epistemological position of the analysis. |
| | 15. | The researcher is positioned as an active human instrument in the research process. The themes do not emerge themselves, but are interpreted and made sense of meaningfully by the researcher. |

***Demonstrating a Rigorous Thematic Analysis***

According to Fereday and Muir-Cochrane (2006), rigour is described as demonstrating integrity and competence in a research study. Providing a clear, transparent and explicit plan and paying careful attention to the phenomenon under investigation illustrates rigour and trustworthiness in qualitative research (Fereday and Muir-Cochrane, 2006). Adherence to the systematic six-step process and fifteen-point checklist in this empirical study demonstrates this qualitative research rigour and trustworthiness. The application of a hybrid deductive and inductive approach further demonstrates qualitative research rigour and trustworthiness (Fereday and Muir-Cochrane, 2006). Theoretical rigour is demonstrated in the sound reasoning and justifications for the choice of methods and their appropriateness for answering the empirical study's research question (Fereday and Muir-Cochrane, 2006). Acknowledging the subjective positioning and viewpoint of the researcher in relation to the phenomenon and

context is important and relates to the interpretive rigour of an interpretivist and qualitative empirical study (Fereday and Muir-Cochrane, 2006). Interpretive rigour is also demonstrated by the researcher explicitly communicating how the data is made sense of and interpreted, and by providing data excerpts that directly link and evidence the analysis findings and interpretations (Fereday and Muir-Cochrane, 2006). Engaging in self-reflection further strengthens the credibility and trustworthiness of the empirical research study and the analytic narrative report (Fereday and Muir-Cochrane, 2006). Reflection and reflexivity leads to a deeper understanding of the data and a richer description of the themes, subthemes and relationship patterns, thereby contributing to the transferability and dependability of the qualitative empirical study findings (Xu and Zammit, 2020).

### 8.6.2 Thematic Analysis Materials

The qualitative data analysis computer software package used to conduct the thematic data analysis was NVivo QSR International Release 1.4.1 for Windows (NVivo, 2021). The virtual semi-structured interviews were transcribed using Otter.ai Pro software. The transcriptions were exported and saved in .docx format and were formatted using Microsoft Office Word Professional Plus 2016 on a Proline desktop computer. Other materials used during the manual coding, theme generation, theme and subtheme refinement and thematic mapping activities included writing pens, colour pens, paper, cardboard and sticky notes. The thematic analysis activities were recorded manually and electronically. A hardcopy codebook was created to document the theory-driven and data-driven coding and memo notes document the theme, subtheme and relationship pattern development and refinement process.

## 8.7 Data Validation

In qualitative social science research, trustworthiness (also described as rigour) is a pragmatic and methodological imperative for researchers to demonstrate the quality, acceptability and usefulness of their data analysis process and findings (Lincoln and Guba, 1985; Korstjens and Moser, 2018). According to Lincoln and Guba (1985) trustworthiness can be achieved by meeting criteria for *credibility*, *transferability*, *dependability* and *confirmability*. These four criteria parallel internal validity, external validity, reliability and objectivity in quantitative research, respectively (Lincoln and Guba, 1985). Other means of achieving trustworthiness in qualitative research are audit trails and reflexivity (Creswell and Miller, 2000; Nowell, et al., 2017; Korstjens and Moser, 2018; Braun and Clarke, 2019).

Based on Braun and Clarke's (2006) six-step thematic analysis process, Nowell, et al. (2017) propose a purposeful and systematic approach to thematic analysis aimed at increasing the rigour, traceability and verification of a researcher's analysis findings. Although systematic, Nowell, et al.'s (2017) approach acknowledges and adapts to the iterative and reflective nature of Braun and Clarke's (2006) method. Techniques for establishing trustworthiness are provided at each step of the thematic analysis process (Nowell, et al., 2017). Nowell, et al. (2017) note that not all suggested techniques will be applicable to every study and that a selection of techniques should be at the researcher's discretion depending on the nature of the empirical study. To demonstrate trustworthiness, Nowell, et al. (2017) align their approach and suggested techniques with Lincoln and Guba's (1985) four criteria, and further incorporate transparency, audit trails and reflexivity as key aspects of their approach. These key aspects are echoed by Creswell and Miller (2000) and Braun and Clarke (2019). Rigour and trustworthiness is further demonstrated through the applied hybrid deductive and inductive thematic analysis method discussed in Subsection 8.6.1 (Fereday and Muir-Cochrane, 2006; Xu and Zammit, 2020).

*Credibility* is concerned with the believability of research findings and the level of confidence that can be placed in the truthfulness of the reported findings (Lincoln and Guba, 1985; Nowell, et al., 2017). Credibility is established when the thematic analysis findings represent plausible information drawn from the raw data and are accurate interpretations of participants' interview answers (Korstjens and Moser, 2018). *Transferability* refers to the degree to which the analysis findings can be transferred to other contexts or settings with other respondents (Lincoln and Guba, 1985). Notably, although the researcher cannot predict the contexts/settings to which future researchers may wish to transfer the research findings, the researcher is responsible for providing thick descriptions so that other researchers can judge the transferability of the findings to their own contexts/settings (Korstjens and Moser, 2018). *Dependability* refers to the consistency of the research findings and the degree to which the data collection and analysis procedures are explicitly and transparently reported, allowing outside researchers to follow, audit and review the dependability of the findings (Lincoln and Guba, 1985). *Confirmability* is concerned with the degree to which the research study findings can be confirmed by other researchers (Korstjens and Moser, 2018). Confirmability involves demonstrating that the interpretations and conclusions of the findings are clearly derived from the interview data, and that the findings are neither figments of the researcher's imagination, nor are they skewed by any researcher bias (Nowell, et al., 2017). Providing explicit and transparent motivations and justifications for theoretical, methodological and analytical decisions – as demonstrated

throughout this research study – are key validation markers for dependability and confirmability (Korstjens and Moser, 2018).

Credibility, dependability and confirmability can be achieved using audit trials (Lincoln and Guba, 1985; Creswell and Miller, 2000; Korstjens and Moser, 2018). *Audit trails* provide an explicit and transparent means of documenting and evidencing all of the steps and decisions made throughout the thematic analysis process, demonstrating the logic and rationale behind the researcher's codes, themes, subthemes, associated relationships, and theoretical inferences (Nowell, et al., 2017; Korstjens and Moser, 2018). Audit trails can be created by keeping records of raw data, semi-structured interview transcripts, reflexive journaling, and memoing (Birks, Chapman and Francis, 2008; Nowell, et al., 2017). Central to the audit trail is reflexivity (Creswell and Miller, 2000; Nowell, et al., 2017). *Reflexivity* is described as the process of critical self-reflection about oneself as a researcher (Nowell, et al., 2017). Reflexivity can be achieved by keeping a reflexive journal, which allows the researcher to document their internal and external dialogue, and track and record their daily logistics of the research process, including their decision-making processes, rationales and personal reflections of their own preconceptions, values, interests and insights information about themselves (Nowell, et al., 2017; Braun and Clarke, 2019). Reflexivity is important in qualitative research because the researcher themselves is a key element of the data collection and analysis method; the researcher is a human instrument (Lincoln and Guba, 1985; Tuckett, 2005). Braun and Clarke (2019, p.6) stress the importance of reflexivity in conducting a rigorous thematic analysis, and emphasise the role of the researcher (human instrument) as being "at the heart of [their] approach" when it comes to producing trustworthy knowledge and theory.

Table 8.8 provides the data validation techniques employed at each stage of the six-step thematic analysis process to establish trustworthiness with the empirical study findings, and correspond to the six steps detailed in Subsection 8.6.1. The techniques employed and their descriptions are drawn from Lincoln and Guba (1985), Creswell and Miller (2000), Tuckett (2005), Nowell, et al. (2017), Korstjens and Morse (2018), Braun and Clarke (2019) and Xu and Zammit (2020). The techniques in Table 8.8 have been selected based on their relevance and applicability to nature of the empirical study and its objectives, and include (in no particular order): *prolonged engagement with data*; *coding framework*; *reflexive journaling*; *memoing*; *diagramming*; *audit trails*; *thick descriptions*; and *transparent reporting*. Table 8.8 also reports on the application of these techniques from the empirical study (after-the-fact).

*Table 8. 8: Techniques used to Establish Trustworthiness in the Qualitative Empirical Study and Thematic Analysis [Source: Informed by Lincoln and Guba (1985), Creswell and Miller (2000), Tuckett (2005), Nowell, et al. (2017), Korstjens and Morse (2018), Braun and Clarke (2019), and Xu and Zammit (2020)]*

| Thematic Analysis Step | Techniques Applied for Establishing Trustworthiness |
|---|---|
| **1. Become Familiar with the Data** | ***Prolonged engagement with data***<br>Active reading and re-reading of all the interview transcripts in NVivo. Active repeated listening to Zoom interview recordings. The data immersion process, involving active engagement with transcriptions, memos, notes and journal entries occurred over a prolonged timeframe, specifically four months, from 22 January 2021 (when the interviews began) to 22 May 2021 (when the report write up was complete). |
| | ***Audit trail***<br>Keep records of all semi-structured interview audiovisual recordings, interview transcripts, handwritten interview notes and reflexive journal entries. Store raw data in secure folders. Chronologically date all audit trial records. |
| | ***Reflexive journal entries and memoing***<br>Document pre-existing thoughts and beliefs, theoretical and reflective thoughts, and growing insights that develop through the data immersion process. Chronologically date all journal entries. During the interview process, manual handwritten journal notes and memos comprised 83 pages. NVivo colour coding strips, colour pens, highlighters and other stationery were used to analyse and become familiar with the data. |
| **2. Generate Initial Codes** | ***Coding framework***<br>Use a theory-driven codebook (a priori template deductively informed by the conceptual and elemental statements/themes and subthemes of the proposed framework). Create a data-driven codebook (inductively coded from the raw data) detailing definitions and exemplar transcribed text. The coding framework made use of NVivo 12's colour coding strips to distinguish codes, themes and subthemes. |
| | ***Audit trail and memoing***<br>Document initial code generation process; memo note interesting and meaningful code features. Document the beginning stages of organising data into meaningful groups and grouping relevant data to each code. Chronologically date all audit trail and memo records. |
| | ***Reflexive journal entries***<br>Reflexive writing throughout the coding process helps the researcher examine how their thoughts and ideas evolve as they engage more deeply with the data. Track emerging impressions of what the data means and how codes relate to one another. Journal entries become auditable evidence. Chronologically date all journal entries. NVivo colour coding strips, colour pens, highlighters and other stationery were used to engage in the initial coding generation process. |
| **3. Search for Themes and Subthemes** | ***Coding framework***<br>Document the refinement of the codebook. Start organising codes (parent and child nodes) into theme-piles. Create a "miscellaneous" theme for codes that do not seem to fit into main themes and subthemes. NVivo 12's colour coding strips were used to organise and distinguish codes, themes and subthemes. |
| | ***Audit trial and memoing***<br>Record the development, hierarchies and relationships between candidate themes and subthemes. Collate all relevant data and interview extracts related to each potential theme and subtheme. Chronologically date all audit trail and memo records. |
| | ***Audit trail and diagramming***<br>Create a draft thematic map with the candidate themes and subthemes. Chronologically date the map's development. The diagrams produced in the findings discussion often originated from thematic maps. |
| | ***Reflexive journal entries***<br>Document the thought, idea and theme development process. Track changes in coding, theme and subtheme understanding. Chronologically date all journal entries. Manual notes, using a variety of colour pens, highlighters, post-it notes and other stationery were used throughout the journaling process. |

| | |
|---|---|
| **4. Review Themes and Subthemes** | ***Audit trail and memoing***<br>Document the review process – review whether the candidate themes and subthemes appear to form a coherent pattern with the coded data extracts (level 1) and whether they relate to the entire data set (level 2). Document decisions and rationale for separating, rearranging, discarding and creating new themes and subthemes, and data extracts. Document clear connections between themes and subthemes and the raw data extracts. Chronologically date all audit trail and memo records. A variety of colour pens, highlighters, post-it notes and other stationery were used during the theme and subtheme review process. |
| | ***Audit trail and diagramming***<br>Document the refinement of the thematic map. Document all decisions and rationale for the conceptualised themes, subthemes and relationship patterns. Chronologically date the map's refinement. The diagrams produced in the findings discussion were refined through theme and subtheme reviews. |
| **5. Define and Name Themes and Subthemes** | ***Audit trail and memoing***<br>Document the detailed analysis for each theme and subtheme. Document the process for refining the broader story of the interpreted data in relation to the empirical study research question. Chronologically date all audit trail and memo records. |
| **6. Produce the Report** | ***Audit trail***<br>Describe the audit trail conducted throughout the thematic analysis; described in this chapter. |
| | ***Thick descriptions***<br>Provide a thick description of the participants, empirical study research process, context and analysis findings (drawing on data excerpts). Participants were richly described in Appendix T. Demographic and key information for each participant includes: gender; age; geographical positioning; degree and/or qualification; occupational position; form of experience (academic, industry or both); duration of experience; and past and current role involvement experience as members of interdisciplinary mHealth physical activity behaviour change intervention app project teams. The empirical research process has been richly described in this chapter. The contextual and thematic analysis findings were "thickly" described in Chapter 9. A multitudinous array of direct participant quotations (excerpts) were drawn from the empirical data, and were thoroughly intertwined in the findings discussions. |
| | ***Audit trail and transparent reporting***<br>Transparently and sufficiently detail the coding and analysis process in the analytical and argumentative narrative (report). Intertwine direct quotes from the transcribed empirical data with the interpreted and meaningful story to enhance the richness and trustworthiness of the thematic analysis. Transparent quoting and evidence is practiced by providing participant codes (PC#). Strengthen the report's trustworthiness by referencing literature that supports the thematic analysis findings and interpretations. The analytic credibility of the researcher depends on the coherence of the argument. A credible discussion includes all relevant results and findings, as well as unexpected, deviant or discrepant cases. |
| | ***Reflexive journal entries***<br>Reference journal entries in the analytic narrative and story to demonstrate self-reflection and the credibility of the thematic analysis. |

In addition to the techniques discussed in Table 8.8, two types of triangulation are employed. The first relates to the empirical study specifically, namely *data person triangulation*, and the second concerns the empirical study and research project as a whole, namely *data source triangulation*. Triangulation is the combining of two or more data sources, methodological approaches, investigators/researchers, theoretical perspectives, and/or data analysis methods (Thurmond, 2001). Triangulation is used to strengthen a research design and increase the trustworthiness of a study's findings, and can be used in qualitative, quantitative and mixed method studies (Creswell and Miller, 2000; Thurmond, 2001).

***Data Person Triangulation***

*Data person triangulation* is achieved by collecting data from different types or levels of participants to gather information from a variety of perspectives (Korstjens and Morse, 2018). This is demonstrated in three ways in this empirical study. Firstly, two types of participants are selected: (1) academics and researchers, and (2) industry practitioners. Both types possess knowledge, skills, expertise and experience in mHealth physical activity behaviour change intervention consumer app design, development and evaluation, but offer different experiences and perspectives. Secondly, participants span several diverse disciplines and specialisations, including: digital health; public health; community health; health science; health promotion; health behaviour change; health psychology; medicine and surgery; kinesiology and human movement science; physical education; sport and exercise psychology; physiotherapy; information systems; computer science; software engineering; mobile computing; user experience design; business management; clinical psychology; law; marketing; and communication and media sciences. Thirdly, participants span several international countries: Austria; New Zealand; Australia; Sweden; Finland; Ireland; Singapore; Scotland; Belgium; and Portugal. This threefold heterogeneity in data person triangulation enriches the quality of the empirical data.

***Data Source Triangulation***

*Data source triangulation* is achieved by collecting data from multiple sources (Thurmond, 2001; Ouma, 2013). Tying in with this empirical study, data source triangulation is demonstrated in this research project as a whole in the use of primary data sources (semi-structured interviews; Chapters 8 and 9) and secondary data sources (literature reviews and academic publications on existing approaches; Chapters 3, 4 and 6).

## 8.8 Ethical Considerations

Conducting the virtual semi-structured interview empirical study requires adherence to several ethical considerations. In research, ethics are standards of behaviour and moral principles that guide a researcher's conduct and aim to protect the rights of persons participating in a study (Saunders, Lewis and Thornhill, 2016). Adhering to ethical principles and practices is imperative in DSR and information systems studies (Myers and Venable, 2014). During the empirical study, all communication and interaction with participants is conducted with respect, honesty, integrity, transparency and trust (Bhattacherjee, 2012). Ethical issues concerning

privacy, confidentiality, anonymity, informed consent and non-maleficence are taken into account (Saunders, Lewis and Thornhill, 2016). The ethical considerations of this empirical study are elaborated on below:

- **Ethical approval:** Prior to the commencement of the empirical study, research ethical approval is obtained at departmental and institutional levels, from the Rhodes University Information Systems Department ethics committee and the Rhodes University Human Ethics Committee (RU-HEC), respectively. Ethical approval involves completing and submitting an online structured human ethics application through the Rhodes University Ethical Review Application System (ERAS). The official "Ethical Approval Letter" is provided in Appendix N.
- **Informed consent:** The principle of informed consent involves the researcher disclosing sufficient information about the study, which allows potential participants to reach a fully informed, considered and autonomous decision about whether or not to participate in the interview process (Myers and Venable, 2014; Saunders, Lewis and Thornhill, 2016). Before the interview session, written informed consent is obtained by providing respondents with a consent form to sign (manually or digitally) and return via email. Informed consent, for both the interview and recording, is confirmed at the start of each virtual interview (verbal informed consent). The informed consent form outlines the purpose of the study, acknowledges the rights of participants and notes the potential uses of the study findings. The informed consent form details participants' rights: the right to voluntary participation; the right to withdraw at any point in time; the right to ask questions and seek clarity on any subject they are asked about; the right to privacy, confidentiality and anonymity; and any anticipated benefits of the research. The "Informed Consent Form" is provided in Appendix O.
- **Privacy, confidentiality and anonymity:** Participants privacy is a key principle associated with several other ethical principle considerations, such as informed consent, voluntary participation, anonymity, and the management and analysis of data and findings (Myers and Venable, 2014; Saunders, Lewis and Thornhill, 2016). Confidentiality involves assuring participants that their identities will be protected and kept anonymous and that no identification information will be disclosed in the data results and analysis findings (Bhattacherjee, 2012). Institutions and organisations of participants' employment are also kept private, confidential and anonymous. Participants are further assured that all thoughts, experiences, attitudes, feelings and

opinions shared during the interview will remain confidential and anonymous. Participants are reassured that the audiovisual recordings will be stored securely in a password protected folder on the researcher's personal computer and personal external hard drive, and that the recordings will not be made accessible to anyone other than the research project supervisor if requested (Myers and Venable, 2014).

- **Relationship building:** Establishing rapport and building trusting relationships with participants is important for fostering communication and openness, contributing to the gathering of rich and valuable data (Bhattacherjee, 2012). Relationship building also assists the snowballing sampling technique, which relies on the researcher-participant relationship to gain access to future participants. The integrity, professionalism and honesty of the researcher in the relationship is important for maintaining momentum in the chain referral process.
- **Honesty and accuracy:** The researcher is responsible for honestly and accurately analysing and reporting the collected data (Myers and Venable, 2014). Data collected from participants must be honestly and accurately reflected in the thematic analysis report and no data findings may be under- or over-stated, so that the report remains true to the raw empirical data (Myers and Venable, 2014). Myers and Venable (2014) also emphasise that design science researchers should not plagiarise any ideas, but instead be honest and truthful in their acknowledgement of data extracts from (anonymous) participants' interview answers. This is practiced in the findings discussions by indicating participant codes (PC#) for excerpts, for example, PC1, PC2, PC3, et cetera.
- **Non-maleficence and risk management:** Non-maleficence is the avoidance of harm to participants (Saunders, Lewis and Thornhill, 2016). Harm may occur through risks to participant's mental, emotional or physical wellbeing, or social or group cohesion, and can take various forms including stress, embarrassment, conflict, pain or discomfort (Saunders, Lewis and Thornhill, 2016). The risk of harm in this empirical study is low for a few reasons. Firstly, the nature of the interview questions is relatively impersonal; questions are orientated towards the nature of their work knowledge and experience, not their close personal lives, beliefs, values, attitudes or experiences. The risk of social or group cohesion is absent given that the interviews are conducted one-on-one. Any risks associated with stress, embarrassment and discomfort is the responsibility of the researcher to mitigate against by remaining friendly, unbiased, engaging, empathetic and attentive during the interview process.

- **Beneficence:** Beneficence is a normative statement of a moral obligation to act for the benefit and welfare of others (Saunders, Lewis and Thornhill, 2016). Beneficence involves removing and preventing any possible harm, and aims to promote the benefit and good of participants (Saunders, Lewis and Thornhill, 2016). The participants are informed that they will neither be compensated nor receive any direct benefits for participating in the study, but will contribute to the research project and the advancement of knowledge in the field. All participants are provided with a summary report of the interview findings after the research project is officially submitted.

## 8.9 Limitations

***Methodological Limitations***

The qualitative linguistic interpretivist approach, grounded in information systems DSR theory, may be perceived as a challenging and complicated approach to apply, and may be challenging to replicate in other research studies. Its challenging nature is apparent in it only being observed in one other information systems DSR doctoral study (Pfeiffer, 2008). This is a limitation, although also an advantage in that it contributes knowledge to a relatively unexplored area of information systems DSR projects. The interview survey strategy employed carries a few limitations, largely relating to the potential presence of biases, all of which were discussed and addressed for mitigation in Section 8.3. The qualitative interview research design bears several limitations and weaknesses that require consideration and counterworking. The researcher forms a key part of the interview instrument, and therefore carries subjective assumptions, perceptions and interests that can potentially influence the quality of the data collected and analysed. The virtual nature of the semi-structured interviews brings challenges and concerns relating to technology, which have been discussed and mitigated against in Subsection 8.4.3. The 45 to 60 minute time limit for the interviews present a limitation in that a longer interview session could yield richer data; however, longer scheduled interview sessions can deter subjects from participating and may be cognitively taxing, which could inadvertently result in poorer quality data. Limitations associated with the snowball sampling technique were discussed in Subsection 8.4.4.

***Empirical Data Limitations***

In terms of the interview topics and questions, a limitation is acknowledged in that, given the comprehensiveness and intricate detailing of the proposed Interdisciplinary mHealth App

Design Framework, it is not feasible to evaluate its every low-level definitive detail during the interview process. For this reason, the interview questions are orientated towards exploring and investigating components and subcomponents pertinent to mHealth physical activity behaviour change intervention consumer apps on a relatively middle-to-high level of abstraction. This, however, also provides opportunities for future research to explore and investigate particular themes and subthemes of the proposed Interdisciplinary mHealth App Design Framework at a finer level of detail. Notably, the low-level intricate details of the framework are indirectly verified through the empirical interview study findings, and are trustworthy given their grounding in the knowledge base Chapter 6. On another note, limitations associated with employing a qualitative data analysis method can be countered and addressed by ensuring data validation. The techniques employed to enhance the trustworthiness and quality of the data analysis process and findings were identified and discussed in Section 8.7.

***Empirical Study Limitations***

Recruiting participants working exclusively in industry and commercial practice was a challenging endeavour. Only three (3) people practising exclusively in industry were willing to partake in the interview study, although twenty-nine (29) were directly contacted and invited via email. The major challenge was finding contact details for industry practitioners without network connections within the commercial companies. Another challenge was finding prospective participants that adequately met the inclusion criteria (Table 8.3). This is due to the specialised contextual focus of the study and the newly emerging nature of the interdisciplinary field. As the interdisciplinary field continues to evolve and progress going forward, it might be easier to find knowledgeable and experienced participants in future studies.

Overall, the recruitment and interview process ran smoothly. The only challenges that interrupted and hindered the interview process a few times were the local and national power and electrical outages in the researcher's city and country of residence. Due to these unplanned and unexpected power outages, two participants withdrew from the study and two other interviews were interrupted midway, but were resumed later that day or the following day.

## 8.10 Conclusion

This chapter has discussed the qualitative DSR linguistic interpretivist approach as the research methodology employed to conduct the empirical ex-post evaluation study on the proposed Interdisciplinary mHealth App Design Framework. This research methodology is used to

answer the fourth research sub-question. The philosophy (interpretivism, specifically linguistic interpretivism) of the evaluation study methodology was outlined and positioned within the overarching pragmatic paradigm of the study. The linguistic interpretivist approach in terms of the DSR artefact evaluation framework, the ontology-based conceptual meta-model evaluation approach, and the linguistic interpretivist conceptual meta-model evaluation procedure were discussed. The interview survey strategy was selected. The qualitative interview data collection design was described, detailing the unit of analysis, the virtual semi-structured interview research instrument, the snowball sampling technique, the virtual semi-structured questions, and the virtual interview guidelines and materials. The qualitative thematic analysis method, and its encompassing hybrid deductive and inductive cognitive reasoning strategy, was discussed. The chapter concluded with the study's ethical considerations and limitations. In essence, the evaluation research methodology presented in this chapter is used to conduct semi-structured interviews with knowledgeable and experienced academics/researchers and industry practitioners in the mHealth physical activity behaviour change intervention consumer app design, development and evaluation real world environment, with the objective of evaluating and revising the Interdisciplinary mHealth App Design Framework. Table 8.9 provides a succinct overview of the evaluation research methodology used to guide the empirical study, and reports on the application of the elements (after-the-fact).

*Table 8. 9: Summary of Methodological Design Guiding the Empirical Evaluation Study [Source: Researcher's own construction]*

| Research Methodology Component | Research Methodology Decision |
|---|---|
| **Research Approach** | • Qualitative Design Science Research (DSR) linguistic interpretivist approach |
| **Research Strategy** | • Interview survey strategy |
| **Data Collection Design** | • Qualitative interviews<br>• Initial planned interview timeframe: Monday, 11 January 2021 to Friday, 22 January 2021<br>• Actual interview timeframe: Friday, 22 January 2021 to Friday, 12 February 2021, with the exception of one postponed interview on Wednesday, 24 February 2021 |
| **Empirical Study Research Question** | • What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context? |
| **Empirical Study Research Objective** | • To evaluate, revise and enhance the quality of the Interdisciplinary mHealth App Design Framework by exploring and investigating its components and |

| | |
|---|---|
| | subcomponents in the context of the mHealth physical activity (promotion) behaviour change intervention app application domain environment |
| **Unit of Analysis** | • The actor, boundary object and supporting artefact, knowledge sharing and process (and activity) content relevant to the mHealth physical activity behaviour change intervention consumer app context |
| **Research Instrument** | • Virtual semi-structured interviews<br>• Interview guide (Appendix P)<br>• Virtual platform: Zoom Video Communications Inc. |
| **Sampling Technique** | • Purposive snowball sampling<br>• The snowball rolled four times through chain referrals |
| **Sample Recruitment Process** | • 40 prospective participants (in academia and industry) were contacted directly via email using a standardised template (Appendix Q), with attachments including a formal signed "Invitation Letter" (Appendix R) and a formal "Information Sheet" (Appendix S). This started the snowballing process<br>• Willing participants signed the form "Informed Consent Form" (Appendix O)<br>• 110 prospective participants (inclusive of academia and industry) were invited<br>• 31 voluntarily willing participants took part in the study (final sample size) |
| **Data Analysis Design** | • Thematic analysis, incorporating a hybrid deductive and inductive cognitive reasoning strategy<br>• NVivo QSR International |
| **Data Validation** | • Prolonged engagement with data<br>• Audit trails<br>• Reflexive journaling<br>• Memoing<br>• Coding frameworks<br>• Diagramming<br>• Thick descriptions<br>• Transparent reporting<br>• Data person and source triangulation |
| **Ethical Considerations** | • Ethical approval<br>• Informed consent<br>• Privacy, confidentiality and anonymity<br>• Relationship building<br>• Honesty and accuracy<br>• Non-maleficence and risk management<br>• Beneficence |

# Chapter 9

## Findings and Discussion

*Interdisciplinary team working is difficult, but it's the only way to develop these apps properly. Software developers aren't from a physical activity background, but they're trying to create physical activity products without knowledge. Then there's physical activity experts who really want to use technology but have no clue how to develop anything. So there's people from these different backgrounds trying to work interdisciplinary, but interdisciplinary work is so difficult, yet it's the only way forward to make the process and products better and more effective.*

*– Participant Code #28 (PC28) (2021) –*



## 9.1 Introduction

An ex post artefact evaluation of the proposed conceptual Interdisciplinary mHealth App Design Framework is an imperative step within the research study process, and particularly the design science research methodology (DSRM) (Venable, Pries-Heje and Baskerville, 2016; Peffers, Tuunanen and Niehaves, 2018; Vom Brocke, et al., 2020). In this research study, the Interdisciplinary mHealth App Design Framework (presented in Chapter 7) is evaluated at Step 4 ("evaluation") of the DSRM, illustrated in Figure 9.1, using the research methodology presented in Chapter 8.

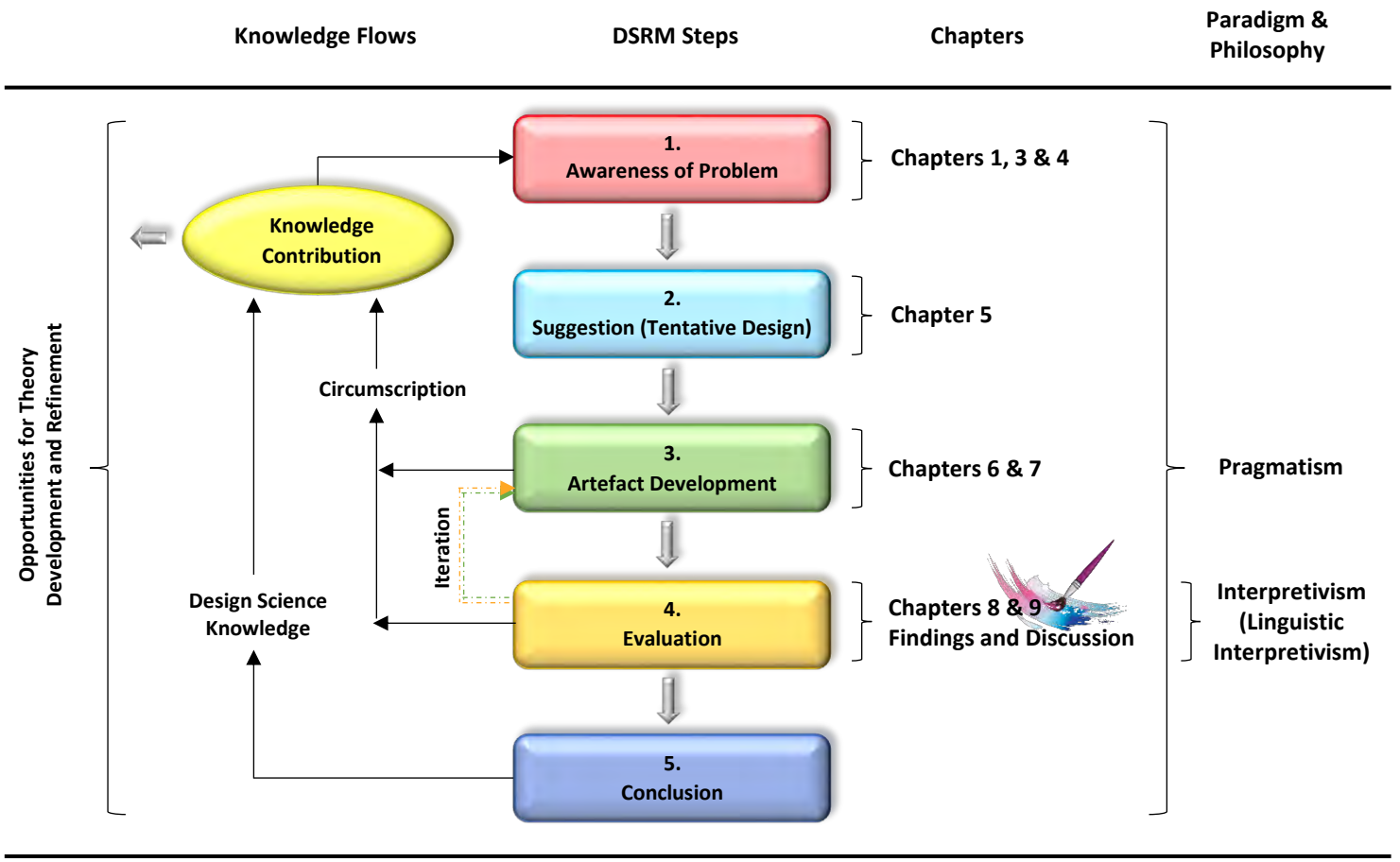



*Figure 9. 1: DSRM: Artefact Evaluation Using an Interview Study: Findings and Discussion [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

To recap the research methodology presented in Chapter 8, the artefact evaluation study employs a qualitative DSR linguistic interpretivist approach, incorporating processes of ontological evaluation and interpersonal verification to confirm, refute and/or improve (that is, reconstruct) the key conceptual components and contextual elements of the proposed

framework. Semi-structured interviews are carried out to answer the following empirical study research question: *"What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?"*. The findings and insights ascertained from analysing the empirical interview data are used to evaluate and inform the refinement and quality improvement of the revised and enhanced Interdisciplinary mHealth App Design Framework in Chapter 10.

This chapter details the sampled participant information, and discusses the findings of the interview study. The interview findings are analysed using a qualitative hybrid deductive and inductive thematic analysis method (presented in Chapter 8, Section 8.6), and employs a hybrid deductive and inductive cognitive reasoning strategy (detailed in Chapter 2). The discussion findings are presented as themes and subthemes relevant to the Interdisciplinary mHealth App Design Framework, evidenced by interview quotations and supporting literature. The chapter concludes with a diagrammatic graphical illustration of the main interview findings.

## 9.2 Research Participants

The interview sample comprised 31 voluntarily willing and consenting participants. This sample size surpassed the preliminary planned estimation for 25 to 30 participants, but did not exceed the maximum threshold of 32 participants (detailed in Chapter 8, Subsection 8.4.4). Participants spanned ten countries, including Austria, New Zealand, Australia, Sweden, Finland, Ireland, Singapore, Scotland, Belgium and Portugal. Of these countries, Australia was the most highly represented. Despite the researcher's numerous efforts, no participants living in England, the United States of America, Canada and other European and African countries were willing to participate in the study. Prospective participants working in England declined participation, reporting busy academic calendars (examination period). The reasons for lack of responses and declined participation from persons in the United States of America and Canada is unknown. As for African countries and South Africa, there is a scarcity of leading researchers and industry practitioners/companies, particularly given the interdisciplinary contextual knowledge and experience required for participation in this interview study.

Appendix T provides a summary overview of the 31 participants' demographic and key information. All participants were coded with unique identifiers to ensure confidentiality and anonymity, using numerical Participant Codes "PC#'s.", for example PC1 to PC31. Appendix

T summarises the following information for each participant: gender; age; city, country (geographical positioning); degree and/or qualification; occupational position; form of experience as either academic or industry (or both); duration of experience (in years); as well as past and current role involvement experience as members of multi- or interdisciplinary mHealth physical activity behaviour change intervention app project teams. Participants' ages ranged 26 to 66 years, and there were 18 females and 13 males. Participants' duration of experience in the field spanned 2 to 23 years. Nine participants were solely academic/research focused, only three were exclusive industry practitioners (further supporting the academic-industry divide), and nineteen hold experience in both academia and industry (albeit, notably, these nineteen participants primarily practice in academia and research projects, but have experience in collaborating with industry and/or commercial companies). All participants, with the exception of one, hold higher postgraduate tertiary education (university) degrees, generally Masters and Doctoral qualifications. As for areas of knowledge, skills, expertise and experience, the participants represent a heterogeneous and diverse sample, including all of the key actor disciplines and relevant communities of practice identified in the proposed Interdisciplinary mHealth App Design Framework (represented by the participants' various degrees/qualifications and occupational positions).

## 9.3 Findings and Discussion

The main thematic findings of the interview study cover: (1) *mHealth physical activity behaviour change intervention app projects*; (2) *goals and objectives*; (3) *actors*; (4) *the interdisciplinary collaborative process*; (5) *objects and supporting artefacts*; (6) *knowledge*; (7) *key challenges and opportunities for future improvement*; and (8) *thematic relationships*. The following subsections discuss the interview study findings.

### 9.3.1 Main Theme 1: mHealth Physical Activity Behaviour Change Intervention App Projects

Mobile health (mHealth) physical activity behaviour change intervention consumer app projects represents the first thematic finding. This first theme aligns with the proposed Interdisciplinary mHealth App Design Framework's fifth theme (namely *"Supplementary Component 1: Project Boundary"*) (Chapter 7, Section 7.7). In total, all participants mentioned 75 multi- and interdisciplinary projects they had been involved with as collaborating team members. Of the 75 explicitly named projects, 11 were identified more than once by different participants. The projects mentioned twice included: Adidas Running app; Flex app; FAME

app; 10 000 Steps web and app; Active Team app; Balanced app; ManUp app; NoHoW Project web and app; MyPlan 2.0 web and app; and SmartLife app. One project, Walk 2.0 web and app, was mentioned four times by four different participants. While repeated reportings of app projects reduces the overall total of identified apps in the participant sample, it holds a valuable advantage in that the different participants are generally of heterogeneous specialist backgrounds, and therefore offer a diversity of views and explanations when answering interview questions, enriching the study data.

Three of the projects have run over several years and are of significant scale. The 10 000 Steps project, funded by Queensland Health, commenced in 2001 as a non-digital local and state level health promotion physical activity intervention, and has successfully grown over the years to become a digital web and app-based physical activity health behaviour change intervention reaching national (Australian) and international scales. Two other projects, namely the NoHoW and PATHway projects, involved large-scale interdisciplinary team collaborations across several European countries, and both have been part of the European Commission's Horizon 2020 initiative – the European Union's largest research and innovation programme with nearly €80 billion of funding available from 2014 to 2020 (European Commission, 2021). The NoHoW project, for instance, was reported by PC27 to be a €5 million five-year project; a figure supported by Stubbs, et al. (2021). Apart from the large-scale and other international projects identified, some participants reported smaller scale research projects conducted over designated periods of time (such as the ManUp, iGo and Worktivity apps).

Table 9.1 provides a summary of the mHealth behaviour change intervention projects identified by participants. Projects largely include research and commercial mobile app-based physical activity behaviour change interventions, although a handful were either dually or solely web-based. Participants described having experience as a multi/interdisciplinary team member on either one or more referenced (named) projects (ranging one to five projects). Table 9.1 details the following: (1) Participant Codes (PC#'s); (2) the respective names/titles of the projects or the mobile app/web-based physical activity behaviour change interventions that participants have collaboratively contributed to during the design, development, evaluation and maintenance process; and (3) the scale and scope of each project or app/web-based intervention, namely on local (community, city, town, suburb, state, province), national (country) or international levels (more than one country, continental).

*Table 9. 1: Participants' App and Web-Based Health Physical Activity Behaviour Change Intervention Projects [Source: Researcher's own construction]*

| PC No. | Name of Project or App/Web-Based Health Behaviour Change Intervention (Research and/or Commercial) | Project Scale and Scope |
|---|---|---|
| **PC1** | • Adidas Running app (Commercial) | • International |
| **PC2** | • Active Coach app (Research and Commercial)<br>• Apps for IMFIT project (IMproving FITness) (Research)<br>• Get Running app (Research)<br>• TODAY app (Research)<br>• OL@-OL@ app (Research) | • International<br>• National<br>• National<br>• National<br>• Local |
| **PC3** | • Adidas Training app (Commercial) | • International |
| **PC4** | • Alexa Device project (Research)<br>• Google Home Device project (Research) | • Local<br>• Local |
| **PC5** | • POEmaS web and app (Research)<br>• CHAP web and app (Research and Commercial) | • National<br>• National |
| **PC6** | • Avatar Reminder app (Research)<br>• Reminder Bot web and app (Research) | • Local<br>• Local |
| **PC7** | • Flex app (Research and Commercial)<br>• Walk 2.0 web and app (Research)<br>• TaylorActive web intervention (Research) | • International<br>• National<br>• National |
| **PC8** | • FAME app (Research and Commercial) | • National and Local |
| **PC9** | • 10 000 Steps web and app (Research and Commercial)<br>• Active Team app (Research and Commercial)<br>• Balanced app (Research and Commercial)<br>• Flex app (Research and Commercial)<br>• Walk 2.0 web and app (Research) | • International<br>• International<br>• International<br>• International<br>• National |
| **PC10** | • 10 000 Steps web and app (Research and Commercial)<br>• Balanced app (Research and Commercial)<br>• Walk 2.0 web and app (Research)<br>• ManUp app (Research) | • International<br>• International<br>• National<br>• Local |
| **PC11** | • WebMD Pain Coach app (Research and Commercial)<br>• TRACK + REACT app (Research and Commercial)<br>• The Pain Toolkit app (Research and Commercial)<br>• RAISE app (Research and Commercial) | • International<br>• International<br>• International<br>• International |
| **PC12** | • WHO ICD10 & ICD11 (Australian Version)<br>• Maintain Your Brain web and app (Research and Commercial) | • National<br>• National |
| **PC13** | • Telehealth MediCare (Commercial)<br>• Clinical Decision Support System (Research and Commercial) | • International<br>• National |
| **PC14** | • Active Team app (Research and Commercial)<br>• IBM Watson Health Assistant (Research and Commercial)<br>• Get Up Girl app (Research and Commercial)<br>• Fitness Link app (Research)<br>• Mums Step It Up app (Research) | • International<br>• International<br>• International<br>• National<br>• Local |
| **PC15** | • FAME app (Research and Commercial) | • National and Local |
| **PC16** | • Walk 2.0 web and app (Research)<br>• ManUp app (Research) | • National<br>• Local |

| | | |
|---|---|---|
| **PC17** | • ePlus web intervention (Research)<br>• eChange project (Research) | • National<br>• National |
| **PC18** | • iGo app (Research)<br>• iCrave app (Research) | • International<br>• International |
| **PC19** | • Strava app (Research)*<br>• Fitbit app (Research)* | • International<br>• International |
| **PC20** | • Nokia Wellness Diary app (Research and Commercial)<br>• NoHoW Toolkit web and app (Research and Commercial)<br>• Oiva app (Research)<br>• BitHabit web intervention (Research)<br>• Eustress app (Research) | • International<br>• International<br>• National<br>• National<br>• National |
| **PC21** | • PATHway project (Research and Commercial)<br>• D1 Now project (Research and Commercial) | • International<br>• National |
| **PC22** | • REMOTE-CR app (Research)<br>• SCRAM app (Research) | • Local<br>• Local |
| **PC23** | • MyPlan 2.0 web and app (Research) | • National |
| **PC24** | • Polar Electro app (Research and Commercial)<br>• Onnikka app (Research) | • International<br>• National |
| **PC25** | • MyPlan 2.0 web and app (Research) | • National |
| **PC26** | • Ayurvedic Medicine web (Research) | • Local |
| **PC27** | • NoHoW Toolkit web and app (Research and Commercial)<br>• Keep On Running app (Research)<br>• EuroFIT (European Fans In Training) app (Research) | • International<br>• National<br>• Local |
| **PC28** | • ABC Project web and app (Research and Commercial)<br>• Jitterbugs app (Research)<br>• Diane (Digital Coaching Assistant) app (Research)<br>• Worktivity app (Research) | • National<br>• National<br>• National<br>• Local |
| **PC29** | • Adidas Running app (Commercial) | • International |
| **PC30** | • SmartLife app (Research and Commercial)<br>• Friendly ATTAC app (Research)<br>• Movie Star app (Research) | • International<br>• National<br>• National |
| **PC31** | • SmartLife app (Research and Commercial)<br>• Conamo app (Research and Commercial) | • International<br>• International |
| **The Strava and Fitbit apps operate on international and commercial levels, but they were solely utilised for national level research purposes by PC19.* | | |

### 9.3.2 Main Theme 2: Goals and Objectives

Goals and objectives represent the second thematic finding. This second theme aligns with the proposed Interdisciplinary mHealth App Design Framework's sixth theme (namely *"Supplementary Component 2: Outcomes"*) (Chapter 7, Section 7.7). The theme of goals and objectives can be divided into three subthemes: (1) *the health goal*; (2) *the project goal and objective*; and (3) *the interdisciplinary collaborative team objective*. Figure 9.2 provides a summary of these goals and objectives.

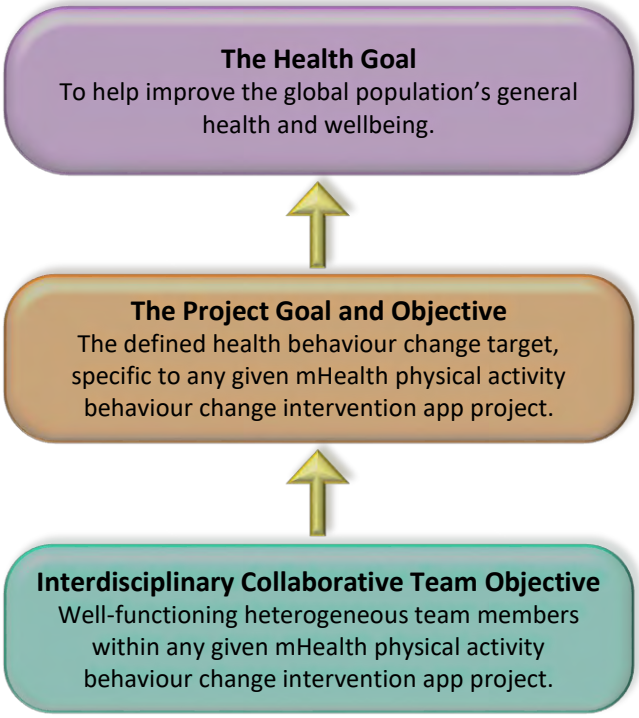



*Figure 9. 2: Goals and Objectives: Interview Study Finding Theme 2*
*[Source: Researcher's own construction]*

With regard to (1) *the health goal* (Figure 9.2, top purple rectangle), participants consistently reported the intention to help improve peoples' general health and wellbeing, through leading healthier daily lifestyle behaviours and particularly increased physical activity. PC20 described the goal as aiming *"to improve people's wellbeing and prevent (sic) getting sick"*, and PC14 stated, more specifically, *"to improve population physical activity"*. PC28 also explained that the key objective *"is to support people [and] help them change their behaviour [to] improve their health"*. Several participants voluntarily justified this objective by emphasising the global prevalence of physical inactivity, obesity, sedentary behaviour and other associated noncommunicable diseases (NCDs), with mentions of cardiovascular diseases, chronic respiratory diseases and type II diabetes. PC19 described that the goal is *"to increase physical activity, obviously, people are very inactive"*, and PC31 stressed the need *"to increase physical activity and reduce sedentary behaviour"*. These worldwide population health concerns were discussed in Chapter 3 and have been perpetually stressed and evidenced in literature for centuries, and increasingly so over the last several decades (Von Hohenheim, 1533; Paffenbarger, Blair and Lee, 2001; Lee, et al., 2012; WHO, 2018a; 2018b; Hall, et al., 2021).

Supporting the attainment of the overarching health goal is (2) *the project goal and objective* (Figure 9.2, middle orange rectangle), which refers to the defined target goal(s) and objective(s)

for each specific mHealth physical activity behaviour change intervention app project. For example, PC1 described the project objective for the Adidas Running app as *"trying to help track the activities and make this easier for the people… by giving them more guidance or giving them more motivation and connecting them with others"*. More specifically, PC26 explained one of the apps as aiming to *"help older people engage in physical activity, who lived in remote locations"*, while PC7 described the Flex app as aiming to *"change people's physical activity without them knowing, through associative learning, by training the mind to pair physical activity with good [and] doing game-based learning"*. Another valuable finding was PC21's insight, who shared that *"it's very useful having and using a core outcome set"* that defines the key project and target population or sub-group objectives. PC24 described something similar, specifically the importance of having a *"set of core features"* for an app to prevent project scope creep and keep the interdisciplinary team focused on key objectives.

Enabling and facilitating the realisation of each mHealth physical activity behaviour change intervention app project's goal(s) and objective(s) is (3) *the interdisciplinary collaborative team objective* (Figure 9.2, bottom turquoise rectangle). This concerns the effective and efficient high-performance functioning of heterogeneous project team members within any given project, and includes team culture, dynamics, communication, collaboration, knowledge sharing, learning capability, negotiation and conflict resolution efforts and practices. High performing interdisciplinary teams rely on these key characteristics (Nancarrow, et al., 2013), particularly in the digital health arena (Sucala and Ezeanochie, 2019; Vos, et al., 2020).

Arrows (Figure 9.2, yellow up-flowing arrows) illustrate the dependencies between each subtheme, specifically their rippling influences and follow-on effects. To explain, a well-functioning interdisciplinary collaborative team is more likely to successfully achieve the defined health behaviour change target of a specific mHealth physical activity behaviour change intervention app project, in comparison to a low-functioning and inefficient team (Hermsen, et al., 2020). Attaining the goals and objectives of multiple mHealth physical activity behaviour change intervention app projects over time in turn helps people to improve their daily lifestyle behaviours on local, national and international levels, ultimately contributing to the vision to help improve the global population's general health and wellbeing. As a caveat, it is important to acknowledge that while complete global population health and wellbeing is idealistic and utopic, working towards the relative improvement of population

health and wellbeing is necessary given the plight of the global NCD and physical inactivity pandemics (Bull, et al., 2020; WHO, 2020c; Hall, et al., 2021).

### 9.3.3 Main Theme 3: Actors

Actors represent the third thematic finding. This third theme corresponds to the proposed Interdisciplinary mHealth App Design Framework's first theme (namely *"Main Component 1: Actors"*) (Chapter 7, Section 7.3). The actors theme can be divided into four subthemes: (1) *the interdisciplinary collaborating team members*; (2) *the project leader*; (3) *external project stakeholders*; (4) *the end users*; and (5) *the significance of interdisciplinary team collaboration*. Figure 9.3 provides a diagrammatic illustration of the key actor theme and subthemes; discussed in the subsections below.

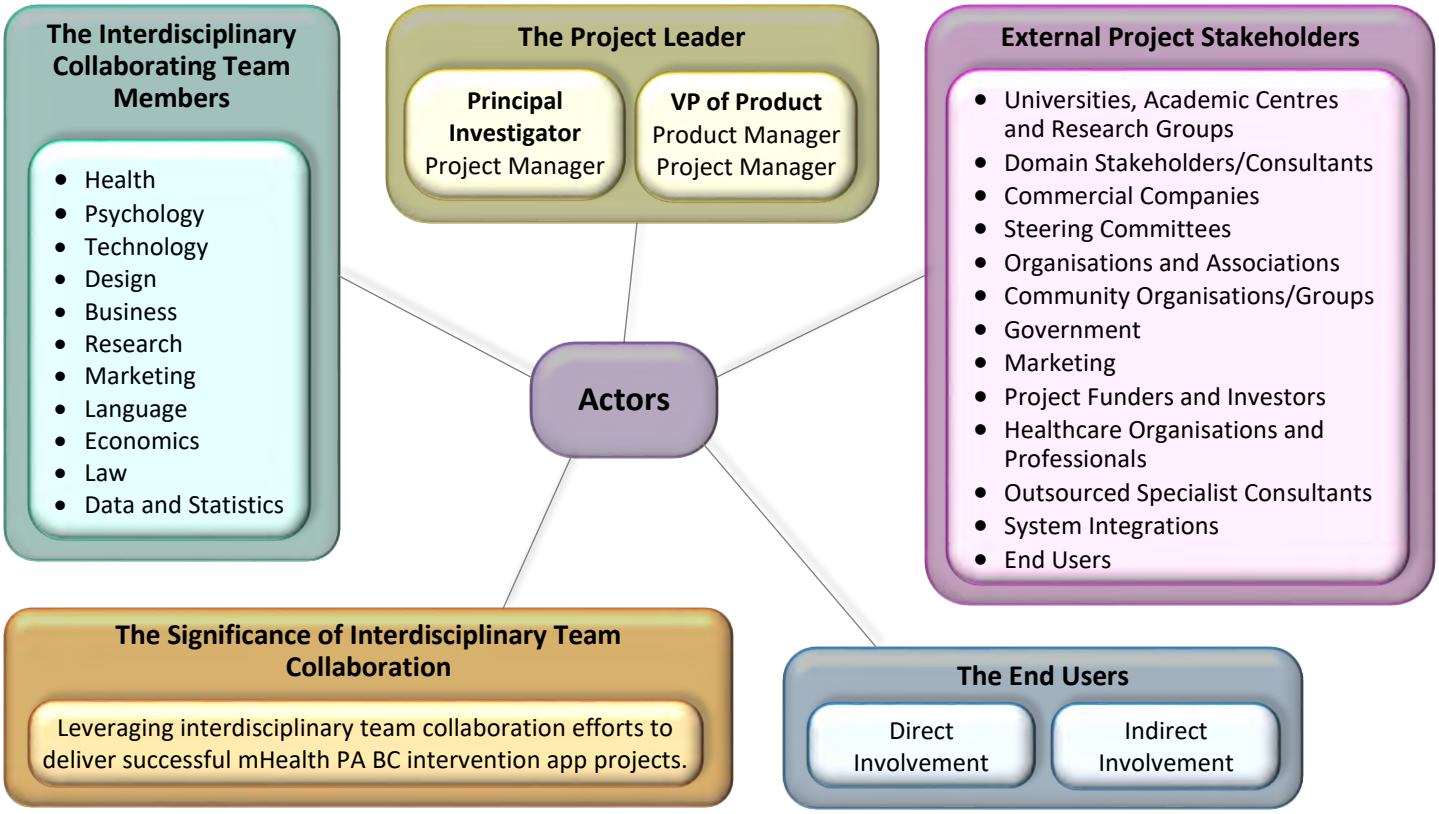



*Figure 9. 3: Actors (Main Theme 3): Interview Study Findings [Source: Researcher's own construction]*

#### 9.3.3.1 The Interdisciplinary Collaborating Team Members

A critical analysis of the interview data revealed participants to identify eleven (11) groups of people involved in the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention app projects. As depicted in Figure

9.3, these groups are categorised as follows: (1) *Health*; (2) *Psychology*; (3) *Technology (including Information Systems and Computer Science)*; (4) *Design*; (5) *Business*; (6) *Research*; (7) *Marketing*; (8) *Language*; (9) *Economics*; (10) *Law*; and (11) *Data and Statistics*.

Table 9.2 summarises the interdisciplinary collaborating team member findings, outlining: the team members' fields/disciplines; the team member roles/areas of specialisation; descriptions of each role supported by participants' quotations; the participant codes (PC#'s) who explicitly mentioned each role; and mHealth physical activity intervention app literature references backing participants' responses. Important to note is that the team member roles identified in Table 9.2 represent the exact terminology utilised by participants. While the categorisations were developed by the researcher, the participants' terms used to identify team member roles has been respected (adhering to the methodology in Chapter 8). This is for ontological validation and linguistic interpersonal verification; providing valuable contextual findings for informing the revision of the Interdisciplinary mHealth App Design Framework (Chapter 10).

While most of the identified team member roles can be supported by literature, there are few roles lacking mention in literature, such as the "Content Team", "Product Designer", "Head of Product Design" and "Release Manager". As illustrated by the light pink colour (Table 9.2), these findings are specific to industry and commercial practice. The lack of mHealth physical activity app literature for these industry team member roles further evidences the reported gaps between academia and industry (Arigo, et al., 2019; Ford, et al., 2019), yet offers novel empirical finding contributions to the knowledge base. Another insightful finding lacking literary support is the "Graphic Designer" role: *"…the creative people, who are not the same as the user experience [design] people… we forget that we need these creative people, but they are very very (sic) necessary"* (PC30). Notably, participants used some terms interchangeably to reference the same role, specifically the developers and programmers. Another noteworthy finding was the lack of participants' mention of team member roles regarding the financial management of mHealth app projects, which would be classified in the "business" group. The lack of financial funding for mHealth app projects was repeatedly reported as a key challenge by participants, yet no mentions were made of a role dedicated to this responsibility.

*Table 9. 2: The Interdisciplinary Team Members (Main Theme 3: Actors): Interview Study Findings [Source: Researcher's own construction]*

| Field or Discipline | Member Role or Area of Specialisation (in singular) | Description(s) of Role/ Specialisation by Participants Interview Quotations (if provided by participants) | Participant (PC) Evidence | Literature Support |
|---|---|---|---|---|
| Health | Health Scientist | • *"...health science people... with expertise in health behaviour science and health problems..."* (PC14) | PC7, PC14, PC16, PC19, PC22, PC28 | Higgins (2016); Dallinga, et al. (2018); Direito, et al. (2018); Haque (2020); Liu and Avello (2021) |
| | Content Team | • *"In the content team we have sport scientists, and they are mostly responsibly for training plans or really putting together exercises for workouts and giving guidance on also running training plans, for example."* (PC1)<br>• *"The content team, like personal trainers and exercise scientists, are responsible for everything that is produced in terms of exercises, content in the app in general...we can also call them sport scientists, like experts in sport."* (PC3)<br>• *"...have knowledge in sports and fitness in general..."* (PC3)<br>• *"...look into trends, things that other [physical activity] apps are doing, or what people [users] are looking for right now, especially during the pandemic, like with things [gyms] being closed."* (PC3)<br>• *"...content is pretty broad, whenever there is text which comes into the app, or an image set, or a new workout video, for example, this is all provided by the content team."* (PC29) | PC1, PC3, PC27, PC29 | Jake-Schoffman, et al. (2017); Chow (2020); Sucala, et al. (2020). |
| | Domain Expert | • *"...the people that are experts in their domains, like physical activity experts, dieticians..."* (PC20) | PC2, PC11, PC20 | Wang (2019); Bendtsen, et al. (2020); Sucala, et al. (2020); Cerbas, et al. (2021). |
| | Sport and/or Exercise Scientist | • *"...sport scientists, like experts in sport."* (PC3)<br>• *"...develop the content using their theoretical backgrounds, like for example, experts on motivation [for physical activity]."* (PC27) | PC3, PC12, PC14, PC16, PC20, PC21, PC22, PC23, PC26, PC27, PC28, PC29 | Higgins (2016); Wiemeyer (2019); Wunsch, et al. (2020); Nicholas, et al. (2021). |
| | Physical Activity Expert | • *"...with expert knowledge in physical activity behaviour, and how to change peoples' physical activity behaviour so that they change their daily exercising habits..."* (PC19) | PC7, PC14, PC19, PC20, PC24, PC27, PC28, PC29 | Dallinga, et al. (2018); Wiemeyer (2019); Bendtsen, et al. (2020); |
| | Personal Trainer | • *"...like personal trainers and exercise scientists, are responsible for everything that is produced in terms of exercises, content in the app in general..."* (PC3) | PC3, PC12, PC29 | Tam (2020); Tavares, et al. (2020). |
| | Exercise Physiologist or Physiotherapist | • *"...working with a physiotherapist that has that knowledge of physical activity..."* (PC19) | PC19, PC22, PC26, PC28 | Wiemeyer (2019); Bendtsen, et al. (2020); Groarke, et al. (2021); Yein (2021). |
| | Public Health "People" | • *"...people with the public health background and knowledge, so I'm public health, but we might have other public health people..."* (PC2) | PC2, PC8, PC15, PC28 | Ben-Zeev, et al. (2015); Ford, et al. (2019); Tam (2020). |
| | Health Behaviour Change Expert/Behavioural Scientist | • *"...with specialist knowledge on how to get people to change their health behaviour like physical activity and exercise..."* (PC21)<br>• *"...behaviour change people help to integrate the intervention principles into the app..."* (PC27) | PC2, PC5, PC7, PC9, PC14, PC21, PC22, PC27, PC28, PC30, PC31 | Yardley, et al. (2015a); Dallinga, et al. (2018); Bendtsen, et al. (2020); Hermsen, et al. (2020); Sucala, et al. (2020); Nicholas, et al. (2021). |

| | | | | |
|---|---|---|---|---|
| Health | Behavioural Epidemiologist | • *[No explanation provided by PC10]* | PC10 | Bul, et al. (2020). |
| | Dietician or Nutritionist | • *"...stuff with dietetics, especially when it's like physical activity and diet, it's kind of dual targets."* (PC14)<br>• *"...people with knowledge and expertise with healthy nutrition..."* (PC24) | PC5, PC12, PC14, PC24, PC27 | Bendtsen, et al. (2020); Wunsch, et al. (2020); Groarke, et al. (2021); Sandborg, et al. (2021). |
| Psychology | Health Psychologist | • *"...have an understanding of health behaviour change..."* (PC19)<br>• *"...have knowledge on theories and models like the stages of change transtheoretical model..."* (PC24) | PC2, PC5, PC9, PC10, PC18, PC19, PC20, PC22, PC23, PC24, PC25, PC27, PC30, PC31 | Yardley, et al. (2015a); Dallinga, et al. (2018); Klonoff (2019); Bendtsen, et al. (2020); Bul, et al. (2020); Hollander, et al (2021). |
| | Clinical/Counselling Psychologist | • *"...also help with depression and anxiety and treatment for that..."* (PC12)<br>• *"...kind of clinical development of the treatment content."* (PC17)<br>• *"...knowledge on addictions... and links with exercise and mild depression and sleep deprivation and stress relief and stuff..."* (PC24)<br>• *"...with experts on emotional regulation, mindfulness and stuff."* (PC27) | PC2, PC9, PC12, PC17, PC19, PC20, PC24, PC26, PC27, PC28, PC31 | Bendtsen, et al. (2020); Ben-Zeev, et al. (2015); Parker, et al. (2019); Groarke, et al. (2021). |
| | Psychiatrist | • *"...had a meeting with a psychiatrist who spoke about the links between physical activity and depression and anxiety and them influencing each other."* (PC28) | PC17, PC28 | Parker, et al. (2019). |
| | Sport/Exercise Psychology | • *"...develop the content using their theoretical backgrounds, like for example, experts on motivation [for physical activity]... or like emotional support and emotional regulation, like using your mind for sport and exercise performance, coping and stress..."* (PC27) | PC27 | Dallinga, et al. (2018); Wiemeyer (2019); Wunsch, et al. (2020); Nicholas, et al. (2021). |
| Technology (Information Systems and Computer Science) | Information Systems "People" | • *"...can include people who specialise in HCI or software engineering or usability experts or PSD [persuasive systems design]... all considered as part of IS [information systems], but distinctions between them."* (PC24) | PC18, PC24, PC26, | van Gemert-Pijnen, et al. (2011); Ben-Zeev, et al. (2015); Hermsen, et al. (2020); Saparamadu, et al. (2021). |
| | Computer Scientist | • *"...the very technical people... come in with pure crude technological oriented models... but you need them involved..."* (PC11) | PC5, PC6, PC11, PC14, PC26, PC28 | Ben-Zeev, et al. (2015); Blandford (2019); Bendtsen, et al. (2020); Bul, et al. (2020). |
| | Health Informatics | • *"...with skills and expertise in ICT and have a health understanding... not health experts or really health based, but can work with health science and physical activity experts to develop it [the app], right?"* (PC16) | PC8, PC9, PC16, PC18 | Pagliari (2007); Blandford (2019); Dugas, Gao and Agarwal (2020). |
| | User Experience Designer/ User Interface Designer/ Usability Expert | • *"...need to make sure the [app] looks nice and make sure the user experience is nice..."* (PC30)<br>• *"...how people use the app, what is important in navigation and the visual aspects."* (PC30) | PC1, PC2, PC5, PC9, PC12, PC15, PC16, PC20, PC24, PC30 | Wilson, et al. (2018); Hermsen, et al. (2020); Wang (2019); Bul, et al. (2020); Sucala, et al. (2020); Cerbas, et al. (2021); Yein (2021). |
| | Product Designer | • *"...can work with [iOS and Android] engineers for the feasibility of designs."* (PC1)<br>• *"the product design team was UX and user interface design before."* (PC3)<br>• *"...make sure that the [user] experience is satisfying."* (PC29) | PC1, PC3, PC29 | Sucala, et al. (2020). |
| | Software Engineer | • *[No explanations provided by participants]* | PC6, PC15, PC22, PC23, PC24, PC28 | Ben-Zeev, et al. (2015); Huang, et al. (2020); Sucala, et al. (2020). |

| | | | | |
|---|---|---|---|---|
| Technology (Information Systems and Computer Science) | Product Engineer/Developer (iOS and Android) | • *"...do the core development of the product [app]."* (PC29) | PC1, PC3, PC29 | Chow (2020); Dugas, Gao and Agarwal (2020); Huang, et al. (2020); Wu (2020). |
| | App Developer | • *"... the the (sic) people who develop the apps, the app developers..."* (PC7) | PC1, PC7, PC17 | Lee, et al. (2018); Mahmood, et al. (2019); Aguilera, et al. (2020); Huang, et al. (2020); Nicholas, et al. (2021). |
| | Developer/Programmer/Coder/ Software Developer | • *"...the people who develop the app..."* (PC9)<br>• *"...does the developing and programming part of the app..."* (PC18)<br>• *"...so they do the programming, coding and developing of the app and all that..."* (PC27) | PC3, PC5, PC9, PC10, PC11, PC12, PC15, PC16, PC17, PC18, PC20, PC21, PC22, PC23, PC24, PC26, PC27, PC28, PC29, PC30, PC31 | Pagliari (2007); Ben-Zeev, et al. (2015); Direito, et al. (2018); Wilson, et al. (2018); Ford, et al. (2019); Cerbas, et al. (2021). |
| | Database (Back End) | • *"...like platform engineering, so not part of product development like developers, but they make sure that we have kind of a base layer of technology that teams can use to build [the app] upon."* (PC29) | PC2, PC3, PC10, PC12, PC24, PC29 | Huang, et al. (2020); Wu (2020). |
| | Game Designer and/or Developer | • *"...develop game elements and incorporate them into the app..."* (PC30)<br>• *"...like gamification..."* (PC31) | PC9, PC12, PC30, PC31 | Lee, et al. (2018); Cerbas, et al. (2021) |
| | Website Developer | • *"...develop like the intervention online... and some are flexible, I don't know how to describe, but like the intervention works online and on a smartphone app..."* (PC17) | PC1, PC3, PC17 | Chow (2020). |
| | Persuasive Systems (Technology) Designer | • *"...knows how to make things compelling [in the app]."* (PC7) | PC7, PC9, PC18, PC24 | Aldenaini, et al. (2020); Haque (2020); Oyebode, et al. (2020); Yfantidou, Sermpezis and Vakali (2021). |
| | DevOps | • *"The DevOps team, so they are ensuring that our systems are operating and scaling."* (PC29) | PC29 | Herman (2019); Stephens, et al. (2021). |
| | Software Architect (with Infrastructure) | • *"...for the app we use different programming languages like iOS and Android, but then also other platforms [and] for our partner API to connect with other groups, other companies, we use different infrastructure with different programming languages."* (PC3)<br>• *"...security certificates [and] infrastructure..."* (PC12) | PC3, PC5, PC12, | Huang, et al. (2020); Sucala, et al. (2020); Saparamadu, et al. (2021). |
| | Networking | • *"... those people who are working on those aspects... you know, like security certificates... and you know, activities or infrastructure related aspects."* (PC12) | PC12 | Huang, et al. (2020). |
| | Machine Learning and Artificial Intelligence | • *"...the people that aren't the same as the software development people, I mean they obviously have software development knowledge, but at the same time are very niche as to how you develop the app... and put logic in the app that makes it perform as if it's artificially intelligent."* (PC9) | PC9, PC15, PC23, PC31 | Aguilera, et al. (2020); Bendtsen, et al. (2020); Stephens, et al. (2021). |
| Design | Graphic Designer | • *"...the creative people, who are not the same as the user experience [design] people... and sometimes we forget that we need these creative people, but they are very very necessary."* (PC30)<br>• *"...skills like experts in look and feel and making it [the app] artistic and pleasant to look at... so like creative design...more like the creative artistic input, like colours and where to put everything..."* (PC30) | PC7, PC10, PC14, PC30 | Molina-Recio, et al. (2020). |

| | | | | |
|---|---|---|---|---|
| Business | Vice President (VP) of Product | • *"...manages and overlooks all of the teams within the product [app]..."* (PC3) | PC1, PC3 | *[Supported by participants only]* |
| | Head of Product Design | • *"...the head of product design is more focused on the people, on the [product design] process and collaboration with different teams..."* (PC3) | PC1, PC3 | Sucala, et al. (2020). |
| | Principal Product Designer | • *"...the principal is really focused on the product [app], the strategy and the user, and making sure the product [app] is going in the right direction."* (PC3) | PC1, PC3 | *[Supported by participants only]* |
| | Product Owner/Manager | • *"The product manager is like having the role of the product owner, so really making sure to talk to the developers about facilitating also many of the SCRUM meetings and workshops as well, and making sure that everything is there before the sprint is started, for example. But they also have an additional responsibility to really make sure we are going in the right direction, and to really think more holistically about the whole product [app]... and making sure everything is implemented well."* (PC1) | PC1, PC3 | Sucala, et al. (2020); Wu (2020); Stephens, et al (2021). |
| | Project Manager | • *"...the project manager manages the [health behaviour change intervention app] project... and sits under the principal investigator."* (PC9)<br>• *"...project managers are usually there for the much larger projects."* (PC9) | PC2, PC9, PC11, PC13, PC16, PC22 | Ni Mhurchu, et al. (2019); Wu (2020); Stubbs, et al. (2021). |
| | Quality Assurance Engineer/ Test Engineer | • *"...is responsible for collecting al the bugs also, but really making sure that the quality is on a high level, and that we get rid of all the bugs."* (PC1)<br>• *"Test engineers will ensure the quality of the product [app] and make sure it's working and things like that."* (PC3)<br>• *"...also checking from a technical perspective that everything [in the app] is working fine and is connecting to the services it needs to, if the data is being saved properly and things like that."* (PC3)<br>• *"...to make sure we are not shipping any new bad [app] quality."* (PC29) | PC1, PC3, PC29 | Chow (2020); Wu (2020); van Haasteren, Vayena and Powell (2020); Roberts, et al. (2021). |
| | Customer Relationship Manager | • *"...sets up guidelines for communication and messaging to the users, so which channel and which kind of communication and messaging is used, for what purpose, so really connecting there [with users]."* (PC1) | PC1 | Chiu, Cho and Chi (2020); Ramdani, Duan and Berrou (2020). |
| | Release Manager | • *"...they review on what's being delivered [in the app] and what's going to be released to the stores [Google Play and Apple App Stores] and they make sure everything is working... there may be updates to different components... so they make sure everything is running, and then they publish the [app] version."* (PC3)<br>• *"...person who is monitoring the [app version] release. They're looking at (sic) into the key metrics and raise the flag if there is something abnormal, for example, the app isn't responding on Android or if it crashes, which which (sic) shouldn't happen. They also monitor user feedback on the [Google Play or Apple] app store and work with our customer happiness support team."* (PC29) | PC3, PC29 | Ben-Zeev, et al. (2015); |
| | Business "People" | • *"...offer knowledge from the business perspective because you have to make sure the app's coming with some business value... creating value in terms of designing the app for the users. They also have knowledge about business models."* (PC18)<br>• *"...business people who do translational and commercial aspects."* (PC22)<br>• *"...it [the app] needs to work and be scalable, otherwise it's not easy to disseminate and exploit in real world situations..."* (PC27) | PC5, PC18, PC22, PC27, PC28 | van Gemert-Pijnen, et al. (2011); Ford, et al. (2019); Bul, et al. (2020); Liu and Avello (2021); Stubbs, et al. (2021). |

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|---|---|---|---|---|
| Research | Researchers (plural) | • *"...helps gather more and more insights."* (PC1)<br>• *"...lots of researchers obviously and these researchers had PhD students who are behind smaller components of the project...and we gave them data to work with or work with them..."* (PC12)<br>• *"...have good knowledge of theories and what the science [academic literature] is talking about..."* (PC18)<br>• *"...get grants for research projects... like to see what research can be done to develop and test the intervention and theory..."* (PC30) | PC1, PC8, PC9, PC12, PC18, PC30, PC31 | van Gemert-Pijnen, et al. (2011); Ben-Zeev, et al. (2015); Dallinga, et al. (2018); Ni Mhurchu, et al. (2019); Bendtsen, et al. (2020); Hermsen, et al. (2020); Nicholas, et al. (2021); Stubbs, et al. (2021). |
| | Research Project Administrator | • *"...the administrators, the the (sic) people who are managing the trial, look at it and then they organise things."* (PC12)<br>• *"...making sure we collect the data we want..."* (PC12)<br>• *"...recruitment... and the enrolment of participants [for research studies]..."* (PC5) | PC5, PC9, PC12, PC27 | Ben-Zeev, et al. (2015); Ni Mhurchu, et al. (2019); Nicholas, et al. (2021); Stubbs, et al. (2021). |
| | Clinical Trial Group/Staff or Field Expert | • *"...trialling the product [app]... that came from the universities, so they're experts on running trials and so forth."* (PC13) | PC13, PC20 | Ben-Zeev, et al. (2015); Wilson, et al. (2018); Mahmood, et al. (2019). |
| | PhD Students (plural) | • *"...PhD students who are doing academic projects..."* (PC4)<br>• *"...PhD students who are behind smaller components of the project..."* (PC12) | PC4, PC12, PC31 | Bendtsen, et al. (2020); Sandborg, et al. (2021); Stubbs, et al. (2021). |
| | Social Scientist | • *"...give perspectives from sociology and qualitative work... to get good in-depth results... otherwise monitoring and evaluating [the app] can be quite quantitative, so the social sciences perspective gives the real human perspective."* (PC15) | PC15, PC18, PC30 | van Gemert-Pijnen, et al. (2011); Baretta, et al. (2019); Liu and Avello (2021). |
| Marketing | Marketing "People"/Scientist | • *"...make sure the app developed is actually disseminated and is available."* (PC11) | PC7, PC9, PC11, PC14, PC28 | Hosseinpour and Terlutter (2019); Truelove, et al. (2020); Aydin and Silahtaroglu (2021). |
| | Marketing Team and/or Brand Design and Media Team (incl. Social Media Marketing Team) | • *"...make sure that the product [app] is really marketed in the best way."* (PC1)<br>• *"The social media marketing team often support us [product designers] when recruiting users via social media, for example, to really have users give feedback and test for us... and they also work with product managers regarding product [app] improvements and releases."* (PC1)<br>• *"...the brand team takes care of the app's branding, like overall the communication visual identity."* (PC3)<br>• *"We also have people working with production [media] in terms of like videos, audio, shooting... to support like the social media channels, for example."* (PC3)<br>• *"...marketing people, you know, in terms of branding and advertising, and how to increase your reach [of the app intervention]."* (PC9)<br>• *"Social media marketing, for example, the fitness coach can post blog articles and images, and videos on the YouTube channel."* (PC29) | PC1, PC3, PC9, PC29 | Hosseinpour and Terlutter (2019); Truelove, et al. (2020); Aydin and Silahtaroglu (2021). |
| Language | Communication Scientist | • *"...for example, for the [Get Up Girl] app, we were looking at what what (sic) language style we should use in the content to appeal to teenage girls [the target group] because they are a very discerning and tough audience and they're very critical. It's easy for them to think some design is really lame or uncool, and communication scientists help with that."* (PC14)<br>• *"...helps with what features can be included in the app... and how to change the users' [physical activity] behaviour..."* (PC25) | PC14, PC25, PC31 | Griffin, et al. (2019); Riley, et al. (2019); Lupiánez-Villanueva, Folkvord and Abeele (2020). |

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|---|---|---|---|---|
| Language | Language Specialists | • *"...make sure that we have the proper texts that are really referring to the goals that we have set and reflecting the initial intentions we had with the product and the specific features, and so that they can be localised in different languages."* (PC1) | PC1 | *[Supported by participant only]* |
| | Writer | • *"...a writer to take evidence based research speak and make it readable for a layperson [app user] and make it more interesting to read for a layperson to try and increase [app] engagement. So like making the content more interesting, potentially around like a story or something to increase engagement within the [app] intervention."* (PC28) | PC28 | Honary, et al. (2019); Hemmings, et al. (2021). |
| Economics | Health Economist | • *"...help with developing interventions and making sure they are really scalable, affordable and cost effective. So they work out the benefits and costs associated with the intervention and they do all the kind of calculations that can figure out whether it's [the app] actually going to be cost effective or not, and the benefits versus the risks, and the sustainability of the intervention as well."* (PC19) | PC12, PC19 | Hosseinpour and Terlutter (2019); Bul, et al. (2020); Wunsch, et al. (2020). |
| | Behavioural Economist | • *[No explanation provided by PC18]* | PC18 | *[Supported by participant only]* |
| Law | Copywriters | • *"...because the app is copyright material..."* (PC1) | PC1 | Bul, et al. (2020). |
| | Data Protection Offer | • *"We have since (sic) GDPR, so the data protection officer makes sure that we are not breaking any privacy laws, for example."* (PC29) | PC29 | Bul, et al. (2020). |
| Data and Statistics | Statistician | • *"...do statistical analysis...and responsible for the data and requesting the data from the system [app]..."* (PC12) | PC6, PC7, PC12, PC18, PC27, PC31 | Wiemeyer (2019); Bendtsen, et al. (2020). |
| | Data Team/Engineers/Scientists and/or Data Analyst/Expert | • *"...implement tracking possibilities, so the data team is there to really get the data or have like, analysis in place that can support us... to analyse did (sic) we have the success that we wanted to achieve or not. They can also help support with the research we're doing in general, doing queries and gathering lists of users for contacting participants, for example."* (PC1)<br>• *"...track different features like usage... so we see how users are interacting with the feature, where they are tapping, going back and forth with the screens, for example. Or when they are opening and closing the app, like each app session and how much time they [users] are spending on each app session. Then they also track activities like in terms of running distance, the pace and everything, so the data team, data engineers and the data science people are... improving how we visualise the data and how we have access to the [physical activity] data."* (PC3)<br>• *"... like we want this information, we want this kind of data to be presented in this format..."* (PC12)<br>• *"...also people who can do data mining to provide an algorithm because the app was tailored [for users]."* (PC30)<br>• *"...like data science..."* (PC31) | PC1, PC3, PC5, PC12; PC20; PC30, PC31 | Wilson, et al. (2018); Blandford (2019); Ford, et al. (2019); Sucala, et al. (2020). |

Notably, depending on their knowledge and personal experience with mHealth app projects, some participants mentioned a few interdisciplinary collaborating team member roles (or areas of specialisation) that have deliberately excluded from the findings in Table 9.2. With regard to the health category, a few mentions were made of medical doctors, clinicians, nurses, carers, cardiologists, pharmacists, endocrinologists, diabetes specialists, healthcare providers, and health service managers. These health roles were excluded because this research project focuses specifically on mHealth consumer apps and expressly excludes medical mHealth apps (argued in Chapter 4, Section 4.2). In terms of the business category, one participant mentioned team member roles for sales, training and education, risk management and human resources. These roles concern the broader roles within a business or company and are outside of the interview study's purpose and scope.

Importantly, while Table 9.2 includes literature sources supporting the various interdisciplinary team member roles, it should be noted that very few literature publications explicitly report all of the team member roles (or areas of specialisation) in mHealth physical activity behaviour change intervention app projects. This is with the exception of a few publications that mention several team member roles or areas of specialisation (such as Van Gemert-Pinjnen, et al., 2011; Ben-Zeev, et al., 2015; Wilson, et al., 2018; Bendtsen, et al., 2020; Sucala, et al., 2020). The findings in this subtheme therefore provide a valuable contribution to knowledge in this area.

#### 9.3.3.2 The Project Leader

When it comes to who is responsible for leading mHealth physical activity behaviour change intervention app projects, a key finding was the distinction between academic/research projects, industry/commercial projects, and projects that involve research-industry collaboration. On the one hand, for academic or research projects, twelve (12) participants identified the *"Principal Investigator"* as the project leader, four (4) participants alternatively referred to this same role as "Chief Investigator", and one (1) participant used the term "Lead Investigator". In addition to this overarching investigator role, ten (10) participants mentioned the role of *"Project Manager"*, and two (2) referred to this same role as either "Project Lead" or "Project Leader". Several participants also discussed the role of a *"Team Leader"* who leads and manages specific teams in a project.

Upon further enquiry with participants, it was clarified that in academic/research projects, project managers are only appointed sometimes, depending on (1) whether the project is in collaboration with industry/commercial practice, and (2) the scale and scope of the project,

with four participants explaining that larger projects are broken up into smaller projects led by project managers. For example, PC9 explains, *"We'd have a project manager that sits underneath the principal investigator, cause there were larger projects and we'd have a project manager as well"*. An alternate response was provided by one participant who, with over two decades of experience in both academia and industry, distinguished between the "Principal Investigator" and "Project Manager" as the project leader in academia and industry, respectively; highlighting a simple distinction in terminology. In comparison, for industry projects, all three (3) of the 'pure' industry participants identified the roles of *"Vice President (VP) of Product"* and next in line "Head of Product", "Product Owner" or *"Product Manager"*, followed by *"Team Leader"*. The "Project Manager" is usually involved when collaborating with product managers, the parent company, and other key external stakeholders (PC1), and works with cross-functional teams to run Scrum meetings and workshops, and manage design iterations and app releases, whereas the "VP of Product" operates on a strategic level (PC1).

For research-industry collaboration projects, the "Principal Investigator" and "Project Manager" roles were both mentioned. Again, depending on the scale and scope of the mHealth physical activity intervention app project, these research-industry collaboration projects may appoint project managers on both sides. Generally, research-industry collaboration projects were initiated by researchers in health science, sport/exercise science, public health, physical activity, or digital health intervention expertise. Figure 9.4 provides a graphical overview of who is responsible for leading mHealth physical activity intervention app projects, with distinctions between academia, industry, and academia-industry collaboration projects.

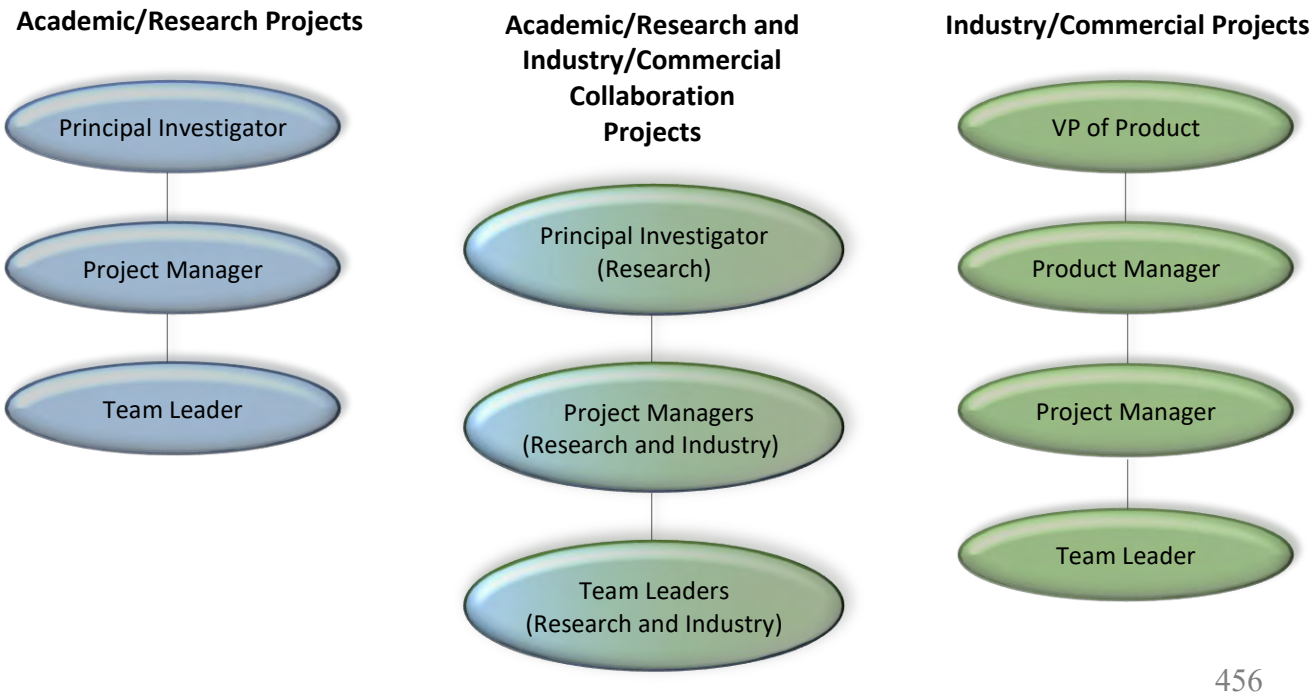





*Figure 9. 4: The Project Leader: Interview Study Findings [Source: Researcher's own construction]*

A few participants elaborated on the significance of a project leader role in mHealth physical activity intervention app projects, particularly in managing, supporting and facilitating the interdisciplinary collaborating team members. PC11 emphasised that *"The key is to have one captain of the ship, who manages the team, makes final decisions and manages the process, of how everything is done and coordinated. The PI I work with, she knows exactly what she wants, she knows the differences and dynamics [between the team members] and she is very clear… you need that person who mediates, facilitates, like the one captain of the ship and the buck stops with them"*. Similarly, PC13 and PC15 stressed the importance of project "champions". PC13 discussed that when *"…working with different people with different knowledge, in multidisciplinary interdisciplinary teams… you need a champion that can really be a good leader, and if you don't have a good leader championing the project, well it's going to fail"*.

PC15 discussed the project leader's role in facilitating good interdisciplinary team communication, collaboration, and shared understanding between heterogeneous team members. For instance, PC15 explained *"We almost expect to not understand what [software] engineers are saying and the engineers won't necessarily understand what we're saying as health science people… so you need those conversations and I think the project leader should lead that… the leader needs to be able to translate things and facilitate shared understanding"*.

The project leader should acknowledge and respect the contributions of each heterogeneous member in the interdisciplinary collaborating team (PC21, PC28). PC21 emphasised a project leader should be able to *"recognise and communicate the importance and value of each member, it's really important, because I think sometimes when you have different perspectives, some people might accidentally undervalue what other people do, and I think that can be a really unfortunate mistake within an interdisciplinary team"*. This argument was reinforced by PC28, who discussed the importance of mutual respect amongst team members and having an *"ally to back you up"* when sharing specialised views and expertise. They (PC28) elaborated, saying *"If it's just me saying ABC and nobody else agrees or is willing to hear me out, then it's not going to be my way right? And I guess if the PI at least sees the value in what I'm trying to say and supports me, then others [team members] might listen. But without that ally, probably nobody's paying attention to what my views are, and that's not right because we're a team and I'm an expert in my area, in sport and exercise science, and I have knowledge and expertise that adds value to the app and intervention content"*.

#### 9.3.3.3 External Project Stakeholders

All participants discussed working with external project stakeholders, with several participants highlighting the significance stakeholders play in designing and producing effective mHealth physical activity behaviour change intervention apps. PC18 stated, *"You have to find the relevant key stakeholders. They're crucial to the project and impact whether the app will be successful or fail… they usually offer valuable insights you wouldn't consider"*. The importance of external project stakeholders is supported by literature on mHealth apps (Christopher, et al., 2015; Petersen, Adams and DeMuro, 2015; Bearne, et al., 2020; Brown, et al., 2020). Christopher, et al. (2015, p.509) discusses "highlighting the importance of key stakeholder inclusion in [mHealth] app development". Bearne, et al. (2020, p.10) emphasises that future mHealth physical activity behaviour change apps "should be rigorously developed with key stakeholders… to optimise their acceptability and impact on PA [physical activity]".

The external project stakeholders identified by participants can be categorised into thirteen (13) groups. These are namely: (1) *Universities, Academic Centres and Research Groups*; (2) *Domain Stakeholders and Consultants*; (3) *Commercial Companies*; (4) *Steering Committees*; (5) *Organisations and Associations*; (6) *Community Organisations/Groups*; (7) *Government*; (8) *Marketing*; (9) *Project Funders and Investors*; (10) *Healthcare Organisations and Professionals*; (11) *Outsourced Specialist Consultants*; (12) *System Integrations*; and (13) *End Users of the product*. Table 9.3 outlines these stakeholders, with brief descriptions and examples provided by participants.

*Table 9. 3: External Project Stakeholders (Main Theme 3: Actors): Interview Study Findings [Source: Researcher's own construction]*

| Stakeholder | Stakeholder Brief Description | Examples provided by Participants |
|---|---|---|
| **Universities, Academic Centres and Research Groups** | • Collaborations with other universities, academic centres and/or research groups. | • Digital Health Centre<br>• Health Psychology Department<br>• Sport and Exercise Department<br>• Sport Research Centre |
| **Domain Stakeholders and Consultants** | • Stakeholders or consultants in the health behaviour change (physical activity) domain. | • Physical Activity Expert<br>• Health Coach<br>• Nutritionist<br>• Personal Trainer |
| **Commercial Companies** | • Working with commercial companies, in the form of partnerships, collaborations or outsourcing specific phases of the project. Generally includes technology, software and gaming companies with expertise in developing mobile apps. | • Apple<br>• Nokia<br>• Strava<br>• Carrot Inc.<br>• Fitbit<br>• Intel |

| | | |
|---|---|---|
| | | • Excivity<br>• Alcatel<br>• Barco<br>• EA Games<br>• Slimming World<br>• Polar Electro |
| **Steering Committees** | • Group of advisors, stakeholders or end user representatives that provide guidance on the project goals, objectives, critical decisions and solution preferences (e.g. app features; look and feel). | • Project Steering Committee<br>• Young Adults Panel<br>• Youth Steering Group |
| **Organisations and Associations** | • Collaborating with relevant organisations, professional associations, foundations and registered societies throughout the project, or during specific phases. | • ISBNPA (International Society of Behavioural Nutrition and Physical Activity)<br>• Heart Foundation<br>• EASO (European Association for the State of Obesity)<br>• Diabetes Association<br>• Psychology Association<br>• Medical Research Council |
| **Community Organisations and Groups** | • Organisations or groups within the target community that are key to the project and reaching the target audience. Collaboration may be with the organisation/group in general, co-investigators, heads/managers or gatekeepers with authority. Can be profit and not-for-profit organisations/groups. | • Active Healthy Kids<br>• Māori Co-Investigators<br>• Pasifika (Pacific) Groups<br>• Community Health Centre |
| **Government** | • Working with government on various levels (e.g. national, local). This can include working with policymakers, obtaining subsidies, lobbying political support, collaborating for specific projects, or assisting the real world implementation process. | • Horizon 2020<br>• NHS (National Health Service)<br>• Department of Health<br>• Department of Education<br>• Medicare (subsidies) |
| **Marketing** | • Working with marketing companies or consultants to translate, commercialise and release the app in real world settings, in the form of partnerships, collaborations, outsourcing, or selling the app. Marketing includes campaigns for promotion, to encourage end user use and advertise the app (e.g. product ambassadors, social media influencers). Marketing can also be employed to recruit participants for research studies. Marketing can be from project onset, during the project, or after the app is produced. | • Slimming World<br>• EA Games<br>• Product Ambassadors<br>• Social Media Influencers (in Fitness, Training and Sport)<br>• Sport Professionals |
| **Project Funders and Investors** | • Funders and investors in the project; can be partial or full funding/investments/grants. | • Slimming World<br>• Project Funders<br>• Government Department |
| **Healthcare Organisations and Professionals** | • Healthcare organisations and/or professionals with knowledge, skills and expertise relevant to the project goals and objectives. | • Health Service Managers<br>• Aged Care Facilities<br>• Physiotherapists<br>• Hospital<br>• Allied Health Care<br>• Health Clinic<br>• Psychology Clinic |
| **Outsourced Specialist Consultants** | • Consultant specialists outsourced for their expert knowledge, skills and expertise, generally at specific phases of the project (e.g. to design and develop the app's game setting and features), or for specific reasons (e.g. to provide workshops). | • User-Centred Design Experts<br>• App Designer/Developer<br>• Game Designer/Developers<br>• Writers (Creative Writers)<br>• Videographers |
| **System Integrations** | • Integrating, connecting and/or pairing with systems and devices in specific companies to exchange key | • Garmin<br>• Polar |

| | | |
|---|---|---|
| | data. For example, working with Garmin, who produce sports watches, to pull users physical activity data. Data is often used for tracking and monitoring end users, or for conducting research studies. | • Peloton<br>• Fitbit<br>• Apple<br>• Samsung<br>• Florence<br>• Cambridge Brain Sciences<br>• NeuroNation |
| **End Users** | • Directly involving end user representatives or end user groups throughout the whole project process (referred to as co-design or participatory design), or involving them at specific phases of the project (e.g. formative research, formative testing, trials). | • End User Representatives<br>• End User Testing Group<br>• End User Trial Group<br>• Participants (Research) |

Table 9.3, likewise with Table 9.2, deliberately excludes specific stakeholder findings, due to the interview study purpose and scope delineation. For example, several mentions were made of clinicians, general practitioners, medical doctors, endocrinologists, nurses and carers; all of which are relevant to medical mHealth apps, but not physical activity mHealth consumer apps.

Lastly, an insightful finding was the suggestion to develop good collaborations and partnerships with companies to improve a project's business and financial model. PC13 explained *"...you have to have these partnerships for these sorts of projects because they will help with the business model and funding"*. This is insightful considering most participants described academic/research projects as being notorious for underfunding, and noting the value of commercial business models to sustain the projects and apps long-term. PC9 explained *"Unfortunately it happens a lot with research, there's no funding to keep the project and app going [and] it will slowly kill the project because our app grow outdated and won't have cool features that all the new apps have*". PC15 also explained the costs involved in maintaining apps, saying *"It's just so expensive to keep an app going, yeah, so unless you can make money out of it, then yeah, it's not going to be around for very long to help people"*. These findings reinforce the ongoing concerns regarding the academic-industry divide, and the need for more commercial business models to sustain long-term funding (Arigo, et al., 2019; Liu, et al., 2019; Ford, et al., 2021). Albeit, literature reports that given the multidimensional nature of mHealth at the intersection of health, technology and finance, developing sustainable business revenue models in such a field can be complex and challenging (Lupiáñez-Villaneuva, Folkvord and Vanden Abeele, 2020).

#### 9.3.3.4 The End Users

All participants discussed the critical role of end users in mHealth physical activity behaviour change intervention app projects. When asked whether they include end users in the mHealth

app process, five (5) participants instantly responded *"Always!"* from the project's commencement. PC26 said *"Always! Always. From day one. Day one. Yep. I'm not gonna go through all this effort to develop something if (A) I haven't engaged them [end users], so they won't want to use it, and (B) it doesn't actually meet their needs"*. PC30 said *"Always! Always. In every project"*. Similarly, PC31 responded with *"Always! Yeah. We involve them from the beginning [and] throughout the process, so it's co-design or participatory design, you know"*. In total, eighteen (18) participants discussed the importance of adopting a collaborative co-design and/or participatory design process, which entails end users involvement at every stage of the interdisciplinary collaboration process. These responses are congruent with growing literature highlighting end users' valuable contributions and co-design and participatory design processes for mHealth intervention app projects (DeSmet, et al., 2016; Carvalho, Jun and Mitchell, 2017; Verbiest, et al., 2018; Walsh, et al., 2019; Brown, et al., 2020; Martin, et al., 2020; Simmich, et al., 2021).

Participants discussed the importance of including end users from the project's initiation with formative research and problem/solution formulation sessions. End users can be in the form of 'end user groups', 'end user representatives' and/or 'end user steering committees'; indicating an overlap with the thirteenth external project stakeholder ("End Users"). PC20 said *"End users are very important and they need to be involved as early as possible"*. Several participants discussed first conducting needs assessments with *"real representatives of the target audience"* (PC15) to accurately determine the needs, preferences, expectations and desired outcomes of the intended end user (consumer) group; however, some noted the costs, time and resources required for these assessments. Three (3) participants mentioned end user involvement in concept solution pre-testing sessions. Eighteen (18) participants discussed involving end users in design-test-refine cycles, where prototypes are formatively tested and refined through methods such as user testing, alpha/beta testing, think aloud sessions and user satisfaction questionnaires; the feedback of which informs the improvement of the app's design and development. After a functional app is developed, participants discussed engaging end users in pilot trails for feasibility, acceptability and user experience testing. Subsequently, end users are involved when conducting small and large-scale trials (such as RCTs). End user involvement throughout the process stages from formative research, conceptualisation, design, development, piloting to summative evaluation – is documented in literature on mHealth physical activity apps (Lee, et al., 2018b; Moorenga, et al., 2018; Ni Mhurchu, et al., 2019; Martin, et al., 2020; Cerbas, et al., 2021; Nicholas, et al., 2021).

However, co-design and participatory design processes with continuous and active end user involvement are not always feasible. Several participants acknowledged the importance of involving end users in every stage of a co-design or participatory design process, yet explained that it is not always appropriate given the target audience, goals and objectives of certain mHealth app projects. Some participants described needing to adjust end user involvement depending on the demographics and characteristics of the target audience, particularly in cases where target groups were elder adults (PC22). *"I think there have been times when co-design or participatory design is not a good idea, and there have been other times when it works really well,"* PC22 explained. In terms of project goals and objectives, some participants described aiming to test the empirical validity of specific health behaviour theory, and did not want end users involved during formative research stages. *"We made a conscious decision to not include end users from the start,"* because *"...we wanted to test the content, BCTs and theories that informed… the intervention. And we didn't want them [end users] to change the content"* (PC27). Generally, end users are *"mostly [involved during] the design, development and testing phases, just not at the initial start"* (PC27).

Notably, there are both advantages and disadvantages to using co-design and participatory design processes (Carvalho, Jun and Mitchell, 2017; Martin, et al., 2020; Ramos-Pedersen, 2020). PC15 expressed *"You can get some really good ideas when you bring in consumers because they have a really different way of looking at things… and you can reach a better app solution at the end if you've incorporated co-design or participatory design"*. Yet, PC15 also notes that the full co-design and participatory design process, with *"...iterative design, development, evaluation, re-development and re-evaluation can be a costly, frustrating and time consuming process, which is why many teams don't necessarily do it all the time"*. The cost, time and resource concerns were also mentioned by a few other participants, as well as the impact of resources and time constraints on the number of co-design iterations.

In light of the challenges associated with full co-design or participatory design approaches, 97% of the participants discussed end user involvement on a formative and summative basis; in which case end users are involved at specific stages of the project process, rather than the whole process. Participants frequently discussed engaging end user groups or end user representatives during formative prototype design-test-refine iteration cycles, trial piloting, and summative trial evaluations. A few participants discussed involving end users in formative research. Five (5) participants mentioned involving end users during the post-release market

stage. Four (4) participants described conducting follow-up qualitative research studies with end users. Some of the methods employed for these various end user studies include diary studies, focus groups, interviews, surveys, prototype testing, think aloud analysis, alpha/beta testing, user experience testing, feasibility and acceptability testing, and trial evaluation methods (such as RCTs).

In essence, on the one hand, end users can be classified as (1) *"directly"* involved in a given mHealth physical activity behaviour change intervention app project. In this instance, the end users actively engage with the interdisciplinary collaborating team members throughout the project process and are recognised as external project stakeholders as 'end user groups', 'end user representatives' or as an 'end user steering committee' ("End Users"). On the other hand, end users can be classified as (2) *"indirectly"* involved in a given mHealth physical activity app project, in which case they are only involved at specific stages of the project process, mainly during the iterative design-test-refine, trial piloting and summative evaluation stages, although potentially also during the formative research, post-release and follow-up stages. The specific stage at which indirect end users are involved depends on the goals, objectives, target audience and other specifics of a given mHealth physical activity intervention app project. Figure 9.5 provides a simplified summary of these two end user distinctions.

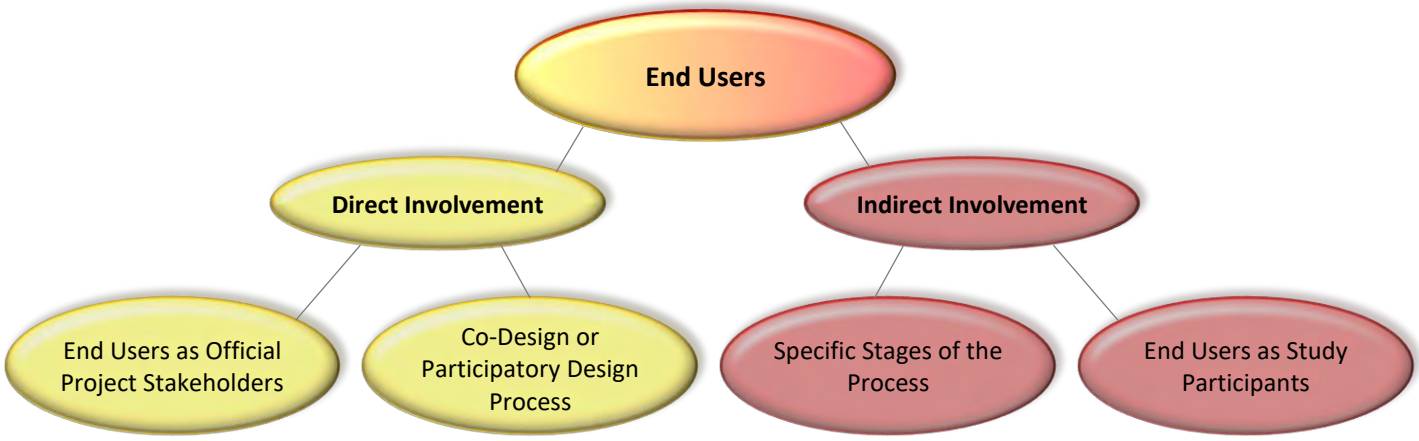



*Figure 9. 5: End Users: Interview Study Findings [Source: Researcher's own construction]*

### 9.3.3.5 The Significance of Interdisciplinary Team Collaboration

All participants acknowledged and discussed the importance of multi- and interdisciplinary team collaboration in mHealth physical activity behaviour change intervention app projects. *"Projects are increasingly becoming more interdisciplinary"* emphasised PC15. PC2 described the importance of high-functioning interdisciplinary collaborating teams, explaining

*"I think it's an important part of the design process, to get that interdisciplinary involvement because people have different strengths [and] all different types of input and feedback is really important, so you really do need to listen to everyone [with] different perspectives"*. Later elaborating *"It's vital that you have an interdisciplinary team and you all respect each other's different expertise and you listen to each other from the start"*. This sentiment was shared by PC26 who, as a professor and project manager with 23 years of academic and industry experience (Appendix T), shared a story about a previous project team member (employee) who *"wasn't on the same page with the rest of the team"*. Despite numerous efforts to help train, upskill and support the employee's professional development, *"…there wasn't any progress"*, which lead to PC26 *"letting them go"*. This demonstrates the importance of interdisciplinary team collaboration and good team-working skills in successful mHealth physical activity behaviour change intervention app projects.

Participants also highlighted the importance of interdisciplinary team collaboration given the complex and evolving nature of the mHealth intervention app field, and especially emphasised the need to bridge the divide between health and technology. *"In society we really need to think about things in not such a siloed approach, like health and technologies are like, they're like brothers and sisters. It doesn't have to be like 'Oh, you're in a different camp, I'm in a different camp'. There really is a need to invest in a society where, you know, our education systems are not so disparate and where interdisciplinary collaboration is encouraged and promoted"* (PC11). *"Technology developers generally have no knowledge of health science and behaviour change, and they come in with pure technological oriented models… but you also need them involved. So you really need to have all of those little strings merged together to braid them so that the product that comes out is useful and meaningful… all of those [interdisciplinary] team members involved is the key"* (PC11). Literature supports this argument (Mohr, et al., 2014; Blandford, et al., 2018; Blandford, 2019a; Walsh and Groarke, 2019; Wang, et al., 2019).

On a final note, when enquired about whether mHealth intervention app project teams should aim for multidisciplinary or interdisciplinary collaboration, PC27 strongly insisted, *"This needs to be a very interdisciplinary collaboration effort. I don't really like the multidisciplinary, we much prefer the interdisciplinary term because multi seems that everyone is working, but they're in their own area, they're not connecting. So we prefer the idea of interdisciplinary cause everyone is connecting properly, communicating and collaborating"*. Considering the 20 years of extensive knowledge, skills and experience of PC27, their

experience as Executive Director of ISBNPA (Appendix T), and their collaboration on large-scale international projects (such as the NoHoW Toolkit, Table 9.1), this is an invaluable and compelling finding from the interview study.

### 9.3.4 Main Theme 4: The Interdisciplinary Collaborative Process

Process represents the fourth main thematic finding of the interview study. This fourth theme corresponds to the proposed Interdisciplinary mHealth App Design Framework's second theme (namely *"Main Component 2: The Interdisciplinary Collaborative Process"*) (Chapter 7, Section 7.4). The process theme can be divided into three subthemes: (1) *key process findings;* (2) *the interdisciplinary process main steps and activities*, and (3) *the nature of the interdisciplinary process*. Figure 9.6 provides an illustration of the key process theme and subthemes; discussed in the subsections below.

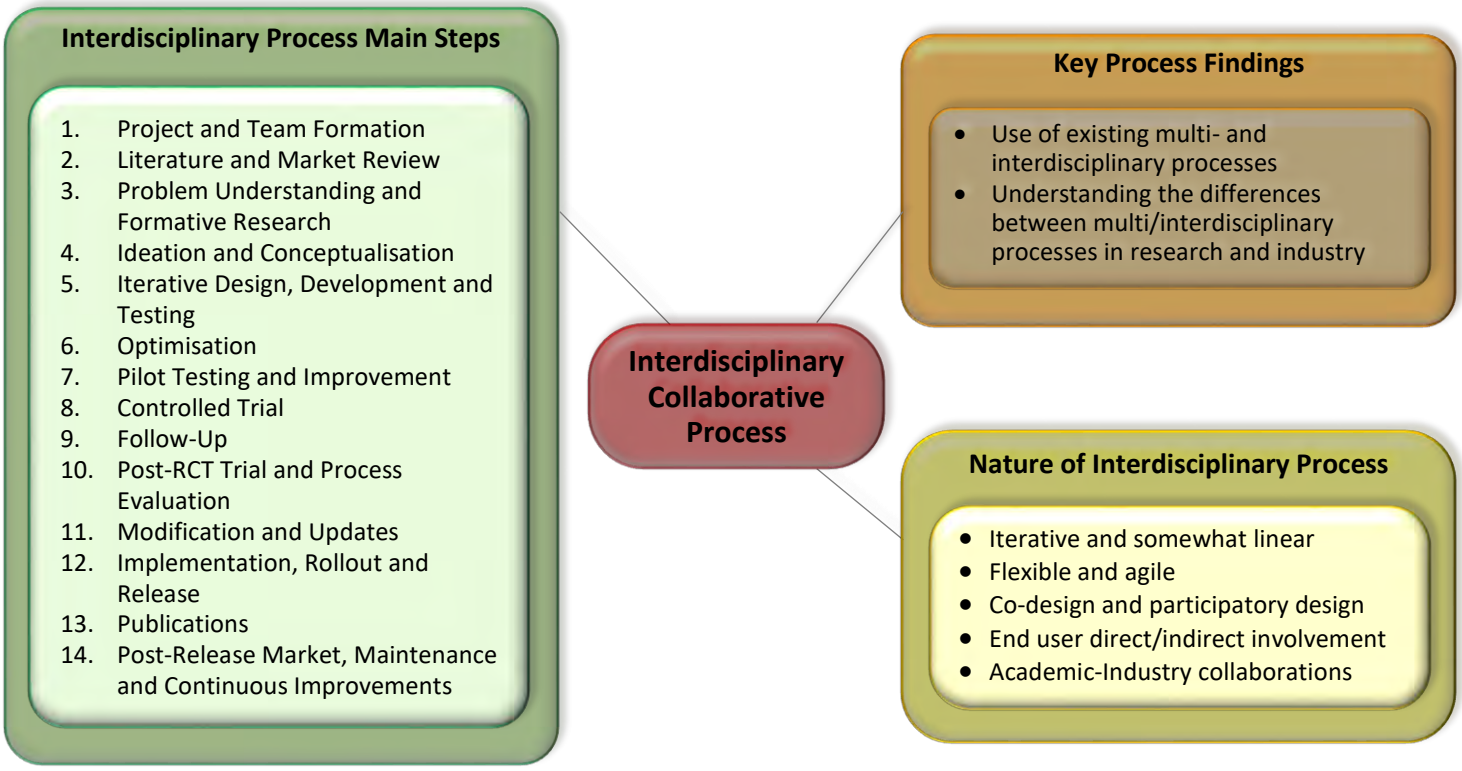



*Figure 9. 6: Interdisciplinary Collaborative Process (Main Theme 4): Interview Study Findings [Source: Researcher's own construction]*

#### 9.3.4.1 Key Process Findings

Two key findings came out of the process data, over and above the interdisciplinary process main steps and activities and the nature of the interdisciplinary process. These two key findings

concern the use of existing multi- and interdisciplinary processes and understanding the differences between multi/interdisciplinary processes in academia/research and industry.

***The use of existing multi- and interdisciplinary processes***

Interestingly, the thematic analysis revealed that only 35% of participants explicitly referenced using a particular process to guide the project team's interdisciplinary collaborative efforts. Dam and Siang's (2020) iterative five-step *design thinking* process was mentioned by five participants, two of which work in industry, one of which works in academia/research, and two of which work in academia/research, but often collaborate closely with industry. Six other processes were identified by six different participants. These processes included: *The Development and Evaluation Process for mHealth Interventions* (Whittaker, et al., 2012); *The Person-Based Approach* (Yardley, et al., 2015a); *The Intervention Mapping (IM) Approach* (Bartholomew Eldredge, et al., 2016); *The MOST (Multiphase Optimization Strategy) Approach* (Collins, Murphy and Stretcher, 2007; Collins, 2018); *The Behaviour Change Wheel (BCW) and COM-B (Capability, Opportunity, Motivation, Behaviour) Model* (Michie, van Stralen and West, 2011); and *The PSDM (Persuasive Systems Design Model)* (Oinas-Kukkonen and Harjumaa, 2009). Of these six processes, the first three have been critically reviewed and analysed in Chapters 4 and 6 (in both the preliminary and detailed critical analyses), and the latter three have been discussed numerous times in Chapters 4, 6 and 7.

Notably, these empirical findings support the literature and theoretical frameworks discussed throughout this research project, evidencing rigour and credibility. However, with 65% of the participants not referencing having used a specific process to guide their team's collaborative interdisciplinary efforts in mHealth app projects, it would seem that despite efforts to advance the knowledge base, there remains a disconnect between the publishing and adopting of proposed multi- and interdisciplinary collaboration approaches. Surprisingly, through further enquiry and discussion with participants, it became apparent that industry practitioners are more consistent and reliable in their application of specific processes (such as design thinking). In comparison, academics were, generally speaking, less consistent and reliable in their use of specific processes and were less likely to follow proposed multi- or interdisciplinary approaches, which would be an expected practice for research professionals. Academics and researchers' inconsistent and less reliable use of published processes may be due to the newly evolving nature of the mHealth intervention app field, the relative infancy of the current knowledge base (in contrast to older, more robust and defined fields/disciplines), and the

general paucity of holistic interdisciplinary processes (the knowledge gap this research project addresses).

Both academics/researchers and industry/commercial practitioners expressed their openness and flexibility towards trying new processes, rather than rigidly and blindly sticking to one process. Howbeit, whilst remaining open-minded, flexible and adaptable, industry practitioners comparably seemed to be more consistent and reliable in their process use, whereas academics and researchers tended to be more inconsistent, sporadic, ad hoc and eclectic by picking up, dropping and mixing up different processes (and parts of processes) as and when desired. This inconsistent and arbitrary use of processes makes building and strengthening the mHealth intervention app knowledge base more challenging, albeit a necessary requirement if the newly emerging digital mHealth intervention app arena is to advance and gain stature.

***Understanding the differences between multi/interdisciplinary processes in research and industry***

Another noteworthy and insightful finding concerns the discernible differences in general process steps between academics/researchers and industry/commercial practitioners, and the impact these differences have on interdisciplinary collaborating teams' time and resources. Academia and research requires teams to go through several additional steps that teams in industry and commercial practice need not perform (Jake-Schoffman and McVay, 2020). These added steps require that academic and research teams expend more time and resources to carry out and complete projects than industry and commercial practitioners, who are permitted to complete their projects in a fraction of the time (Arigo, et al., 2019; Ford, et al., 2019; 2021). *"Industry is very rapid paced, so things happen really really (sic) quickly. Whereas academia, things happen very slowly, much slower than industry"* expressed PC26.

Participants working in academia and research frequently reported performing the following steps as part of the mHealth app project process: conducting literature reviews; developing research project proposals; assembling suitable/fitting teams; finding and securing funding or grants; and identifying and securing external stakeholders (which can be challenging in gate-kept communities and organisations). In addition to these steps, many academics and researchers discussed conducting long-term RCTs, which halt the project's progression and prevent any subsequent updates or adjustments to the mHealth intervention app, and mentioned performing post-trial follow-up studies after an extended waiting period, which further prolongs the overall project process. PC22 said, *"It's a little bit frustrating where you're*

*running a clinical trial, and you've got to just leave your [mHealth app] intervention the way it is. And you might know after a short period of time that there's actually some things that need changing or updating, but by virtue of the RCT design, you're compelled not to make those changes until perhaps years later"*. These additional steps can add years to an already lengthy process. On average, it can take *"two, three, four or even five years"* (PC31) to complete one project. *"It took almost all of my time, it took five years"* (PC27). *"It's a long process… about a year and a half to two years to go through the whole RCT process"* (PC30).

The problem with prolonging the whole project process is that by the time the mHealth physical activity behaviour change intervention app is ready for dissemination, marketing and real world release, there is a high risk that the product will be obsolete and require core software and content updates (Blandford, et al., 2018). PC28 expressed with frustration *"It's a huge challenge because we're also trying to create something that's super innovative and up to speed. And so by the time we go through our whole process, already what we've done is out-of-date. [We need] a more rapid research process or perhaps better collaboration with industry, and you have to have a robust research process, but at the same time it's so lengthy that it becomes redundant very quickly. Even by the time you publish a paper, the technology that you're referring to is probably no longer on the market, so it's a huge challenge"*.

Academics and researchers often discussed the obligation to analysing, reporting and publishing the project data as an official and mandatory part of the academic/research process, which too demands time and resources. There is also seldom enough time to write papers that share tactic knowledge/experience, or report on the detailed steps/activities of the project process, over-and-above the mandatory publishing of formative or summative results. *"I feel really guilty about this myself because this is something that often happens, the project ends and you don't have any resources, and you have to go on to another project"* explained PC20.

All of the above-discussed examples evidence the key differences between multi/interdisciplinary processes in academia/research and industry/commercial practice. These examples also evidence additional steps and activities that academics and researchers are required to carry out as part of the mHealth physical activity behaviour change intervention app project process; steps that industry and commercial practitioners need not perform. On the one hand, while contributing to and advancing the mHealth knowledge base is imperative, the added process steps and activities necessary for academic and research practice, over-and-above industry and commercial practice, negatively effects the timeframes in which projects

can be executed and finalised. For this reason, industry and commercial apps tend to hit the real world market at a much faster pace, are more readily and easily updated through version releases, and are able to attract consistent revenue from early on, thereby aiding the development of a sustainable business and financial model for such projects (Ford, et al., 2019; Arigo, et al., 2019; Ford, et al., 2021). The major critiques of this, however, is that industry and commercial projects often lack theory- and evidence-based foundations, are seldom reported on in terms of process design and development, and the impact of their effectiveness on peoples' physical activity behaviours and daily lifestyle habits generally remains unmeasured after being released on public consumer app market stores (Arigo, et al., 2019; Milne-Ives, et al., 2020). PC27 noted the lack of health behaviour change theory and BCTs in commercial apps, discussed the importance of developing mHealth physical activity apps that have a solid *"theoretical background"*, and explained that theoretical constructs need to be *"scientifically tested for effectiveness"* to determine *"what works and what doesn't work"*.

#### 9.3.4.2 The Interdisciplinary Process Main Steps and Activities

All participants described the interdisciplinary collaborative process as comprising several steps. For each step, participants detailed the various activities team members engage in, the methods they employ, and the objects they utilise and create, to achieve the project goals and objectives (to produce a mHealth physical activity behaviour change intervention app product for consumers). Participants used the terms *"steps"*, *"stage"* and *"phase"* synonymously to reference the main components of the interdisciplinary collaborative process.

***Identifying the key process steps and activities, and pinpointing the differences and similarities between multi/interdisciplinary processes in research and industry***

To recap a few key points discussed above in Subsection 9.3.4.1, all participants described the mHealth intervention app project lifespan as comprising a series of several steps, with each step encompassing certain activities. Overall, in total, participants mentioned a variety of process steps and activities. Participants primarily practicing in academia and research generally identified more steps than those primarily practicing in industry. Even within academia and research, there were slight differences in the mentioned steps and activities. Nevertheless, despite there being some differences, some steps and activities were repeatedly reported by participants. Table 9.4 provides a summary of the steps and activities regularly mentioned by participants, outlining: the names of each step (categorised by the researcher), the key activities performed in each process step, descriptions of each step and its activities

(quoted by participants), the participant codes (PC#'s) that discussed each step, and references of literature supporting the steps and activities identified by participants. As is the case with Table 9.2, many of the precise terminologies utilised by participants to identify steps and activities has been respected (adhering to the methodology in Chapter 8). This is for ontological validation and linguistic interpersonal verification; providing valuable contextual findings for informing the revision of the Interdisciplinary mHealth App Design Framework (Chapter 10).

As outlined in Table 9.4, the main steps identified are: (1) *project and team formation*; (2) *literature and market review*; (3) *problem understanding and formative research*; (4) *ideation and conceptualisation*; (5) *iterative design, development and testing*; (6) *optimisation*; (7) *pilot testing and improvement*; (8) *controlled trial*; (9) *follow-up*; (10) *post-RCT trial and process evaluation*; (11) *modification and updates*; (12) *implementation, rollout and release*; (13) *publications*; and (14) *post-release market maintenance and continuous improvements.* Table 9.4 distinguishes whether each step and its comprising activities are applicable specifically to academia/research (white background), specifically to industry/commercial practice (cerise shaded background), or both academia/research and industry/commercial practice (horizontal cerise and white lined background). These distinctions represent the differences and similarities in steps and activities carried out by interdisciplinary teams in academia and industry (Liu, et al., 2019; Jake-Schoffman and McVay, 2020). The additional academic/research process steps and activities are apparent through these colour-coded distinctions.

Important to note is not all of steps and activities are mandatory to perform. Depending on the project and process plan, the project goals and objectives, and the time and resource constraints, the interdisciplinary team may choose to apply certain steps and activities, and omit others. For example, an academic/research team may decide to not conduct step 8, a controlled trial, due to time and funding constraints or an RCT may not be a part of the project goals and objectives. PC31 explained, *"We don't always do RCTs. We want to partner with health organisations… to release the app as a campaign or… to test it in natural settings, so there's no real control group"*. PC31 justified their reasoning by highlighting weaknesses of RCTs. *"With RCTs, there's always motivation of your participants to just be a good participant. But what we really want to know is does the app design result in longer or better use; will it help people change their [physical] activity, because most apps in real life are downloaded, looked at twice and then never looked at again. You can't do that with a RCT. Rather get some in-app statistics to see which features they like or what profiles they have, and from there you can learn to improve you app, but unfortunately in academic projects there's mostly no room for doing that"* (PC31).

*Table 9. 4: Process Steps and Activities (Main Theme 4: Process): Interview Study Findings [Source: Researcher's own construction]*

| Process Step | Activities in Process Step (key findings) | Description(s) of Process Step and Comprising Activities by Participants Interview Quotations (if provided by participants) | PC Evidence | Literature Support |
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| **Project and Team Formation (Academia/Research)** | • Team formation<br>• Team building<br>• Project idea and rationale<br>• Project management framework<br>• Project process<br>• Timeline<br>• Budgeting and funding<br>• Research project proposal<br>• Ethics<br>• Stakeholder selection and steering committee appointment<br>• Team meetings (within the team and with stakeholders) | • *"When you have an idea to prepare a project, it usually it starts with getting a team together. Then you have team building and there's a lot of workshopping with the team to try and figure out the specifics of the project."* (PC20)<br>• *"...scope out the project..."* (PC26)<br>• *"...write up and flesh out the timeline...and we work out the costings..."* (PC4)<br>• *"Identify what project management framework and process we're going to use..."* (PC26)<br>• *"...we work out the methodology and process..."* (PC4)<br>• *"...we like to try use a co-design process for the product..."* (PC5)<br>• *"...grant applications to secure money..."* (PC9)<br>• *"...sought funding and received funding to develop the app."* (PC15)<br>• *"...if we need ethical approval, we'll get all of that..."* (PC26)<br>• *"...get a stakeholder group in place...and form the steering committee."* (PC26)<br>• *"...the project management, develop timelines with task break downs allocated..."* (PC13) | PC4, PC5, PC9, PC12, PC13, PC15, PC16, PC20, PC21, PC26, PC27 | Scandurra, Hägglund and Koch (2008a); van Gemert-Pijnen, et al. (2011); Edwards, et al. (2018); Wilson, et al. (2018); Ford, et al. (2019); Kowatsch, et al. (2019); Hermsen, et al. (2020); O'Cathain, et al. (2020); Stubbs, et al. (2021). |
| **Project and Team Formation (Industry)** | • Company business strategy<br>• Business problem prioritisation<br>• KPIs (key performance indicators)<br>• Team task allocation | • *"We have business goals at the top level, so what is our company trying to pursue? The business goals are usually broken down into sub-goals [and] we can translate these sub-goals into customer problems, what business problems we are trying to solve. With those problems, you task a set of teams or a single team so address the problem in the best way."* (PC29)<br>• *"The team decides on their own KPI, and what they want to achieve within a given period like within the quarter, so that sets the deadline."* (PC29)<br>• *"...we explore our different goals in the company..."* (PC3)<br>• *"...determine who is responsible for what..."* (PC4) | PC1, PC3, PC4, PC13, PC26, PC29 | Scandurra, Hägglund and Koch (2008a); Wilson, et al. (2018); Ford, et al. (2019); Jake-Schoffman and McVay (2020). |
| **Literature and Market Review (Academia/Research)** | • Literature review<br>• App market review | • *"We do a literature review to see what's already out there."* (PC20)<br>• *"We usually do a literature review on the behaviour, like physical activity, and we determine what the main determinants of the behaviour are."* (PC30)<br>• *"...if we have time, we look at existing research as well."* (PC3)<br>• *"We sometimes do a systematic review of, you know, literature and what's been done in the field we're going to work on..."* (PC31)<br>• *"...doing literature reviews to explore the current issues and what solutions have already been implemented..."* (PC6) | PC2, PC3, PC6, PC9, PC11, PC15, PC19, PC20, PC21, PC24, PC30, PC31 | Curtis, Lahiri and Brown (2015); Verbiest, et al. (2018); Wilson, et al. (2018); Blandford (2019b); Kowatsch, et al. (2019); O'Cathain, et al. (2020); Sucala, et al. (2020). |
| **Problem Understanding and Formative Research (Academia/Research)** | • Problem identification<br>• Problem understanding<br>• Needs analysis<br>• Requirements gathering<br>• Formative research | • *"Developing a sense of what the problem is or what needs to be addressed or solved."* (PC15)<br>• *"...do the needs analysis to determine what the needs are..."* (PC26)<br>• *"...we do a needs assessment of what is needed, what do we need to work on."* (PC30)<br>• *"Identifying the target group, the need, you know, understanding the problem, talking with end users about what the problems are..."* (PC2)<br>• *"...we do some formative research with focus groups to ask people like 'What do you think of physical activity?', 'Are you active?', 'What do you think are the benefits of physical activity?', and 'Would you use an app to help improve your physical activity?' etc. Determine what would work and not work for that target group."* (PC9)<br>• *"...with formative research, when we start talking to the target group, we might also do semi-structured interviews, or focus groups, or surveys, which would be more quantitative data, but we may also do qualitative stuff first because it provides rich information..."* (PC9) | PC5, PC6, PC9, PC11, PC14, PC20, PC22, PC23, PC25, PC26, PC28, PC30, PC31 | Whittaker, et al. (2012); Blanson Henkemans, et al. (2015); Curtis, Lahiri and Brown (2015); Wight, et al. (2015); Yardley, et al. (2015a); Bartholomew Eldredge, et al. (2016); Mummah, et al. (2016); Smith, et al. (2016); Carvalho, Jun and Mitchell (2017); Direito, et al. (2018); Edwards, et al. (2018); |

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| | | • *"...with co-design, we do some formative research, interviews with end users to get their ideas..."* (PC14)<br>• *"...doing some formative research with the target group, like focus group discussions, to get some insights or track the problem...the barriers, the challenges..."* (PC28)<br>• *"We do some kind of qualitative or sometime quantitative research with potential users or with people who already use something similar, get an idea of their desires."* (PC31) | | Verbiest, et al. (2018); Wilson, et al. (2018); Blandford (2019b); Wang, et al. (2019); O'Cathain, et al. (2020); Sucala, et al. (2020). |
| **Problem Understanding and Formative Research (Industry)** | • Business problems (customer problems)<br>• Problem Statement – Empathise and Define (Design Thinking) | • *"We can translate these sub-goals into customer problems, what business problems we are trying to solve."* (PC29)<br>• *"...following the design thinking approach, so we gather insights, empathising with users... really trying to get to know our users."* (PC1)<br>• *"We start with the problem we want to explore, we call it like the discovery phase, we explore the problem more... more understanding of the problem. We do this until we have a problem statement, and make sure it's a real problem, a problem we definitely need to tackle."* (PC3)<br>• *"...some surveys or interviews with our users... we're really trying to figure out about (sic) their motivations and needs, and what is also hindering them from doing sports and physical activities. We've also done diary studies with users to really learn more about their habits, when they're starting to work out with our products..."* (PC1) | PC1, PC3, PC13, PC29 | Scandurra, Hägglund and Koch (2008a). |
| **Ideation and Conceptualisation (Academia/Research)** | • Creative brainstorming<br>• Ideate possible solutions (what is reasonable and possible given the heath behaviour, physical activity, and technological medium, app platform)<br>• Ideation and conceptualisation of possible solutions within team, as well as with relevant stakeholders and end user representatives<br>• Conceptualise and outline the theoretical underpinning and the associated intervention content links (determinants, theoretical constructs, mechanisms of change, behaviour change techniques, persuasive design principles)<br>• Specify the core features (PSDM)<br>• Create user stories and usage scenarios<br>• Iterations are optional | • *"Conceptualise the idea, define the target group and what kind of intervention we want"* (PC5)<br>• *"Start off with conceptualisation were you're trying to work out, okay, for what we want to achieve, what should the platform look and feel like, and what should the app do?"* (PC10)<br>• *"Identify what are the technology requirements? What must the intervention do?"* (PC20)<br>• *"So generally, kind of start with what we call conceptualisation..."* (PC2)<br>• *"Sometimes we collect information from all the experts and their requirements and ideas, and iteratively working with that and doing workshops to come up with a solution."* (PC20)<br>• *"We did some co-design to determine what should be included in the app, what should the app look like, how will it function..."* (PC15)<br>• *"... go into an early design phase where we just throw out ideas based on what we've heard from users [formative research]..."* (PC2)<br>• *"It can be useful to define a minimum viable product; absolute minimum requirements"* (PC20)<br>• *"Underpinning the app with theory is really important, like health behaviour change theory or the COM-B model; identify what theory you're implementing in the intervention"* (PC21)<br>• *"...identifying the health intervention content will be suitable for the target group, end users or the particular purpose of the app..."* (PC22)<br>• *"We wanted the content, the theoretical background, the behaviour change techniques, the behaviour change theories that informed us what we wanted to add to the intervention."* (PC27)<br>• *"...underpinned by a conceptual model, which is theory-driven, and have a model that outlines all of the elements of the intervention, what they lead to, and then what would be the outcomes. The theory or evidence base."* (PC28)<br>• *"...look at what kinds of methods could be used to, to change the behaviour..."* (PC30)<br>• *"...we have a set of core features, set of potential core features... that's at least a good common ground to start talking about which of these core features will be fleshed out in the actual design. Then asking if something is missing, or is there something that can be added to the list, or is there something not really needed. There's about 30 [persuasive system design] features, but it doesn't mean the more you have, the better... it might be enough that you have a handful of maybe 6 or 9 [persuasive systems design] features, rather than 15 or 25. The core set of features kind of directs your thinking."* (PC24) | PC2, PC3, PC5, PC6, PC7, PC9, PC10, PC11, PC12, PC14, PC15, PC16, PC20, PC21, PC26, PC28, PC29, PC31 | Craig, et al. (2008); Oinas-Kukkonen and Harjumaa (2009); Hekler, et al. (2011); van Gemert-Pijnen, et al. (2011); Whittaker, et al. (2012); Mohr, et al. (2014); Blanson Henkemans, et al. (2015); Curtis, Lahiri and Brown (2015); Wight, et al. (2015); Yardley, et al. (2015a); Bartholomew Eldredge, et al. (2016); Mummah, et al. (2016); Smith, et al. (2016); Carvalho, Jun and Mitchell (2017); Direito, et al. (2018); Edwards, et al. (2018); Verbiest, et al. (2018); Wilson, et al. (2018); Arigo, et al. (2019); Blandford (2019b); Ford, et al. (2019); Kowatsch, et al. (2019); Wang, et al. (2019); Hermsen, et al. (2020); O'Cathain, et al. (2020); Sucala, et al. (2020). |

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| **Ideation and Conceptualisation (Industry)** | • Ideation and conceptualisation of possible solutions within team<br>• Design sprints<br>• Prioritise ideas (ICE scores)<br>• Create user stories and usage scenarios | • *"In the ideation phase, thinking about possible solutions, maybe what are the technical limitations or any technical opportunities as well."* (PC1)<br>• *"Sometimes we're using design sprints, we might have four days sprint, or if we do it quick, like two days sprint, and do some other things like lightning talks and sketching time…"* (PC1)<br>• *"In the ideation phase we look into competitors, or trends, what other app are doing, not only fitness apps, but other apps in general, what people are doing. We also get lots of insights from social media, and we gather some learnings. From this ideation phase, sometimes we do design sprints where we take the week to explore ideas into more specific solutions or a solution or a set of solutions. If we don't do design sprints, we ideate within the team."* (PC3)<br>• *"We have a brainstorming session where everyone generates ideas, ideation phase, and these ideas are mapped out with an ICE score, so Impact, Confidence and Effort. Based on this prioritisation technique, the solution is split into smaller chunks, which are then actually achievable within a sprint, and we have two weeks cycles of sprints. And those packages are then usually written in user stories."* (PC29)<br>• *"We try create some kind of usage scenarios, for like, a physical activity app, trying to imagine all the steps that a user may go through and in different scenarios, like if it's bad weather or options to either go for a run or a walk. We try go through these scenarios."* (PC31) | PC1, PC3, PC26, PC29 | Scandurra, Hägglund and Koch (2008a); van Amstel, et al. (2017); Arigo, et al. (2019); Hermsen, et al. (2020); Jake-Schoffman and McVay (2020); Sucala, et al. (2020). |
| **Iterative Design, Development and Testing (Academia/Research and Industry)** | • Creative designing of the app<br>• Iterative design, development and testing process (iteration cycles and feedback loops)<br>• Iteration cycles from low fidelity prototypes (initial, early designs) to high fidelity prototypes (fully functional, working app)<br>• Iterative refinements and improvements based on testing results and user feedback<br>• Operationalise theory, behaviour change techniques and persuasive systems design principles into interactive app features<br>• Design, develop and test both the (1) intervention content, and (2) usability/user experience<br>• Alpha app version(s)<br>• Alpha testing (internal testing)<br>• Beta app version(s)<br>• Beta testing (end user testing)<br>• Testing: A/B testing; concept testing; usability testing (e.g. think aloud technique, SUS scale)<br>• Debugging<br>• Quality testing/assurance | • *"…designing and developing something… a relatively continuous iterative process. I like the idea of an iterative design process where you can work through different ideas and work towards some optimisation…"* (PC22)<br>• *"We enter this kind of iterative process where we produce a prototype and we test it within the team first [alpha testing], then some beta testing and lab testing, refining the intervention, test it with the target group."* (PC28)<br>• *"Design the material and test it with many prototypes. Prototype testing ideas and the full app product, letting users use it and get feedback. There's a lot of iterations in all of this"* (PC30)<br>• *"…that's when creative design comes in… [and later] we test it within the lab with the researchers, and then give the app to the target participants and have them test it for usability testing. We see what can be changed and make any changes we want."* (PC7)<br>• *"We'll go into a prototyping phase and develop something. Then we do some pre-testing where we take the early prototype out to user representatives, get them to look at the app, make sure the messages are understandable and that the app is usable and meeting their needs. Then we take their feedback and refine and improve the prototype."* (PC2)<br>• *"…using co-design for the development process, so there'll be alpha testing with the team and then beta testing with users…"* (PC14)<br>• *"There's a whole design phase where we may do some A/B testing with apps in terms of design or the location of certain features, like the font, the interface, etc, and we see how users respond to certain elements and design features."* (PC31)<br>• *"We start developing stuff and once we have a bit of a prototype, an alpha version and we do some internal testing first to see if it actually works and makes sense, or find things that are really crappy and try fix it up. Then we have a beta app version that we expose it to users and ask them to test it, they might come into the lab, and we ask them to play with the app and we might video record them and ask them questions or do think aloud sort of sessions. Or sometimes we ask them to download the app, and get the users to use the app for a couple of weeks and then report back to us, or we have an interview with them and ask how it went with the apps, what they liked and didn't like and what can be improved. We then take that feedback on board and modify the app, and sometimes if we have enough time and money, there will be another round of user testing."* (PC9) | PC1, PC2, PC3, PC5, PC6, PC7, PC8, PC9, PC10, PC11, PC13, PC14, PC15, PC16, PC17, PC18, PC19, PC20, PC21, PC22, PC23, PC24, PC25, PC26, PC27, PC28, PC29, PC30, PC31 | Craig, et al. (2008); Scandurra, Hägglund and Koch (2008a); Hekler, et al. (2011); van Gemert-Pijnen, et al. (2011); Whittaker, et al. (2012); Mohr, et al. (2014); Blanson Henkemans, et al. (2015); Curtis, Lahiri and Brown (2015); Wight, et al. (2015); Yardley, et al. (2015a); Bartholomew Eldredge, et al. (2016); Mummah, et al. (2016); Smith, et al. (2016); Carvalho, Jun and Mitchell (2017); Direito, et al. (2018); Edwards, et al. (2018); Verbiest, et al. (2018); Wilson, et al. (2018); Arigo, et al. (2019); Kowatsch, et al. (2019); Wang, et al. (2019); Hermsen, et al. (2020); O'Cathain, et al. (2020); Sucala, et al. (2020). |

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| **Iterative Design, Development and Testing (Academia/Research and Industry)** | | • *"Once we've worked out the design solution on paper, we test back and forth with stakeholder groups and end users until we have a beta app developed."* (PC26)<br>• *"...get feedback on the design elements, the look of the intervention and app, the functionality and the engagement."* (PC28)<br>• *"...go into the user testing phase where we go through iterations and get feedback from users, so we kind of show the app to them, integrate their feedback, then show it to them again, that kind of thing."* (PC21)<br>• *"...then you do alpha, alpha (sic) and beta, beta (sic) testing..."* (PC5)<br>• *"...start building a prototype and involving end users in the process, it might be like a mock-up evaluation or think aloud evaluation with a functional prototype..."* (PC20)<br>• *"We go deeper into the design and make it more high fidelity, we do the screens, the flows, and work closely with the developers to know if it's feasible to implement. This design, development solution phase is lots of collaboration. Then we do usability testing or concept testing, and we do a UI review. We also do A/B tests, so we have the control group and the other group with the new variant, and have the A/B test running for like four, five or six weeks, and users provide feedback."* (PC3)<br>• *"Sometimes we do internal testing, or sometimes we launch it with an A/B or A/B/C test as well to see what's working best here..."* (PC1)<br>• *"...we had version 1.0 and tested it with users... gathered lots of feedback... then had version 2.0. Then did a beta testing period... understand how users interact with the app, user experience things, until we reached version 2.01 to use for the trial."* (PC27)<br>• *"We went through a few design and development cycles with the toolkit [app] working with users and improving it, we had several versions, and we were testing and improving over and over, it was very fast."* (PC27)<br>• *"...start developing an app and bringing in user representatives for intensive sessions of running through the app and asking questions like 'Would you actually use this app?', 'How would you incorporate using the app in your daily life?'. And try to add value to the app... it might be that you end up with a solution that's quite different to the original app that was conceived..."* (PC15)<br>• *"To design and develop the app we went through a full co-design process with the users, they provided input on what they needed and what they'd want the app to look and feel like. We'd take their feedback and then go to the next [design and development] iteration..."* (PC2)<br>• *"Then the prototyping phase of design thinking, we came up with the prototype with mock-ups and different levels of fidelity, so first paper and cardboard low fidelity prototypes, and then built it up to a working high-fidelity prototype. We would show the users the mock-ups and get their feedback. Then finally we did testing with the working app. But it's not like one step because prototyping, the design and developing and testing is an iterative process. So it can iterate and cycle twice, or maybe even five or six times."* (PC18)<br>• *"Test the app with our stakeholder groups and fix up our bugs."* (PC26)<br>• *"...there might be more than one rounds of iterative improvements and feedback loops to discover issues with the app."* (PC9)<br>• *"With the UI review, in parallel we have the QA team, the Quality Assurance team that is also checking the app from a technical perspective, so they make sure that everything is working fine, is connecting to the services it needs to be connected to, if the data is being saved properly and things like that."* (PC3)<br>• *"...then quality assessment and feedback, it's a quality improvement cycle..."* (PC26) | | |

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| **Iterations (Industry)** | • Design sprints | • *"With the possible solutions, we might have possibilities for feedback in the company, in-house testing, but then also maybe testing wireframes or mock-ups with users, depending on the size of the project. We also do the reviews, like code reviews and design reviews, and make sure everything works for both platforms Android and iOS."* (PC1) | PC1, PC3, PC26, PC29 | van Amstel, et al. (2017); Hermsen, et al. (2020); Jake-Schoffman and McVay (2020); Sucala, et al. (2020). |
| **Optimisation (Academia/Research)** | • Optimisation (MOST) | • *"Instead of doing a traditional RCT, we are looking at following the multiphase optimisation strategy (MOST), where we run micro-randomised trials to understand what parts of the intervention or what behaviour change techniques, or what intervention functions are having a positive effect, and which are having a negative effective or having no effect. Then coming out with an optimal intervention, so we take away the bits that don't work or aren't used [by users], so we end up with an app that is meant to be the most effective, right. Then after that, we might move into like an effectiveness trial to see if the app intervention has an effect on, for example, health outcomes, like increased physical activity."* (PC28) | PC22, PC28 | Collins, et al. (2005); Collins, Murphy and Stretcher (2007); Collins, (2018); Arigo, et al. (2019); Blandford (2019b); Kowatsch, et al. (2019); Sucala, et al. (2020). |
| **Pilot Testing and Improvement (Academia/Research)** | • Pilot trial study (small group)<br>• Pilot with end users (either in a controlled environment or allow people to use the app in their natural settings/everyday lives)<br>• Pilot test: usability, user experience, acceptability, feasibility, proof of concept, potential effect size<br>• Gather participant recruitment information (for RCT)<br>• Refinements and improvements based on pilot trial results and user feedback<br>• Refine app, ready for RCT or rollout | • *"After beta testing, there'll be a pilot RCT to get pilot data..."* (PC14)<br>• *"Then we tested the app in a pilot study, so the pilot study is usually about usability, acceptability, feasibility sometimes, and getting more feedback from people who actually use the app as part of their daily life for a period of time."* (PC2)<br>• *"Then did some pilot testing where we gave people the app on iPads that were loaded with data so that it could connect to the internet, and got some feedback from users. Once the pilot testing was done, changes were made to the app..."* (PC15)<br>• *"We do some kind of feasibility study where we get the users involved in using the app in their daily life for a few weeks, and that's very important."* (PC20)<br>• *"If there's funding, we might do pilot testing and feasibility..."* (PC9)<br>• *"The pilot trial to check feasibility and the kind of implementation issues that we might have later..."* (PC21)<br>• *"...then we roll it out in a pilot test where we see if the app's actually changing what we want it to change, so the psychological or behavioural construct. The pilot test informs us how much power we'll need for the RCT. So we're testing proof of concept, feasibility, how big is the effect? That way we can figure out how many people we need to recruit for the RCT and how we need to adjust our scalability or reach."* (PC7)<br>• *"We conduct some pilot study, trial study with the target group where they use the app intervention for a while and we try to see the feasibility, the acceptability and maybe some preliminary efficacy. So did it help change their physical activity behaviour in any way, did it improve anything or the outcomes? This informs further refinements and improvements to the app, and will give us an idea about the magnitude of the change that we could expect to see for a bigger trial."* (PC28) | PC2, PC5, PC6, PC7, PC8, PC9, PC10, PC12, PC14, PC15, PC20, PC22, PC23, PC25, PC26, PC27, PC28, PC30 | Craig, et al. (2008); Whittaker, et al. (2012); Mummah, et al. (2016); Smith, et al. (2016); Wilson, et al. (2018); Blandford (2019b); Kowatsch, et al. (2019); Wang, et al. (2019); Hermsen, et al. (2020); O'Cathain, et al. (2020); Sucala, et al. (2020). |
| **Controlled Trial (Academia/Research)** | • Usually performed in academic projects, albeit not always (not performed in industry)<br>• Participant recruitment (large group)<br>• Clinical controlled trial design (preferably RCT, but can be a non-randomised design)<br>• Lock in the intervention for the whole trial period/duration | • *"If we have a bigger project, we usually do a clinical trial. How long the trial runs for depends on the project and how long it is expected for the intervention to have an effect, so maybe one year, half a year, sometimes longer, like NoHoW was 18 months." (PC20)*<br>• *"...scientific test for effectiveness..."* (PC27)<br>• *"RCTs, some are short term for three months; others longer, up to a year or more."* (PC7)<br>• *"...we start recruiting people... these trials are usually quite tightly controlled so there's a whole bunch of eligibility criteria for people to be allowed into the study, like for example, they're not already using a physical activity app, or they're not very active people."* (PC9)<br>• *"While updates were made to the app (after pilot testing), participant recruitment happened, the app was distributed to the sampled participants and baseline measurements were collected,* | PC2, PC5, PC6, PC7, PC9, PC11, PC12, PC14, PC15, PC16, PC20, PC21, PC22, PC23, PC24, PC25, PC27, PC28, PC30, PC31 | Craig, et al. (2008); van Gemert-Pijnen, et al. (2011); Blanson Henkemans, et al. (2015); Wight, et al. (2015); Yardley, et al. (2015a); Bartholomew Eldredge, et al. (2016); Mummah, et al. (2016); Smith, et al. (2016); Carvalho, Jun and Mitchell (2017); |

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| **Controlled Trial (Academia/Research)** | • Usually evaluates effectiveness, but can also evaluate proof of concept, feasibility, acceptance, user experience, sustainable usage.<br>• Usually measures health and behavioural outcomes, effect sizes and long-term impacts | *and then we just waited three months. After three months people were invited back to have the measurements taken again."* (PC15)<br>• *"As academics, we do more formal evaluation, usually focusing on health outcomes, like physical activity level, or a proxy of that."* (PC22)<br>• *"The goal for many of these academic projects is to evaluate the effectiveness of the app, but it depends on the study size and how rigorous the RCT ends up being, whether it's small or big based on the budget and funding…"* (PC9)<br>• *"…trialling to find out if the intervention is effective…after which you can take it into practice and real world context [roll out]."* (PC5)<br>• *"An RCT is about whether the users physical activity behaviour changed over time, like is the app and intervention effective or not?"* (PC9) | | Verbiest, et al. (2018); Wilson, et al. (2018); Arigo, et al. (2019); Ford, et al. (2019); Kowatsch, et al. (2019); Wang, et al. (2019); O'Cathain, et al. (2020). |
| **Follow-Up (Academia/ Research)** | • Qualitative research (optional: can be performed at the end of an RCT)<br>• Follow-up (optional: waiting period, after RCT) | • *"Then there was a follow-up."* (PC15)<br>• *"After the effectiveness, then qualitative research and follow up with a subset of users so that we get more feedback to improve the app more before it goes into the full implementation or rollout phase."* (PC2)<br>• *"…we had follow-up points to see if people maintained their behaviour change."* (PC17) | PC2, PC12, PC14, PC15, PC17, PC22, PC31 | Craig, et al. (2008); Whittaker, et al. (2012); Wilson, et al. (2018); O'Cathain, et al. (2020). |
| **Post-RCT Trial and Process Evaluation (Academia/Research)** | • Pragmatic trials (after RCT)<br>• Ecological trials (after RCT)<br>• Process evaluation | • *"In a couple of studies we've done pragmatic trials, ecological trials, but it wasn't so much whether their physical activity behaviour changed, but whether they sign up for the app or downloaded the app and use it or not. We might want to find out how many people downloaded the app, or how many people used the app, so it's more about engagement metrics, and in a more natural environment without any eligibility criteria. Ecological trials are different to doing RCTs… typically we wouldn't go straight into an ecological trial without knowing whether the app actually works or not, if it's effective or not."* (PC9) | PC9, PC10, PC21, PC26 | Craig, et al. (2008); van Gemert-Pijnen, et al. (2011); Blanson Henkemans, et al. (2015); Bartholomew Eldredge, et al. (2016); Ford, et al. (2019). |
| **Modification and Updates (Academia/Research)** | • Modify and update the app after the trial study, based on trial results and feedback<br>• Perform software updates<br>• Remove trial-specific elements<br>• Prepare final app version for roll out | • *"…based on feedback, it's a combination of software updates and improvements… we usually need to make some changes after the RCT so that the app is suited for use outside of the research context."* (PC14)<br>• *"…from the trial, participants gave me feedback that I could use to improve it."* (PC6)<br>• *"…after the clinical trial, of course developing the solution further based on the feedback."* (PC20) | PC9, PC10, PC12, PC14, PC15, PC21, PC22, PC23, PC25, PC26, PC28, PC30, PC31 | Craig, et al. (2008); Yardley, et al. (2015a); Mummah, et al. (2016); Verbiest, et al. (2018); Wilson, et al. (2018); Blandford (2019b); Wang, et al. (2019); O'Cathain, et al. (2020). |
| **Implementation, Rollout and Release (Academia/Research and Industry)** | • Revise or develop business/ commercial model, scale up model and financial model<br>• Translation and commercialisation process (app goes to market)<br>• Licencing and contract (between research and industry)<br>• Implementation, rollout and release the app to the market (app store), available for download by users in real world settings<br>• Dissemination with marketers and campaign | • *"After changes were made to the app, it was rolled out."* (PC15)<br>• *"Before every [app version] update there is regression testing to make sure already in-house that nothing is broken. After an update, the release managers look into the key metrics and raise the flag if there is something abnormal, for example, if the app is not responding or crashing, which shouldn't happen."* (PC29)<br>• *"We have the release managers, they get together every two weeks because we release new app updates every two weeks, and they do a review on what's being delivered and what's going to be released to the app stores. They make sure everything is running properly, and then they publish the app version on for review on the app store, and then it gets published."* (PC3)<br>• *"…it will be shipped in two weeks in the app product, we don't ship anything without implementing a certain level of tracking, so we also measure what we're doing. Shipping means usually that we are providing an update of the app for the existing customers or for every new customer to automatically get the newest version of the app."* (PC29) | PC1, PC2, PC3, PC5, PC8, PC14, PC15, PC22, PC26, PC29, PC31 | Craig, et al. (2008); van Gemert-Pijnen, et al. (2011); Blanson Henkemans, et al. (2015); Bartholomew Eldredge, et al. (2016); Mummah, et al. (2016); Wilson, et al. (2018); Ford, et al. (2019); Ford, et al. (2020). |

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| | • Field trial testing can be conducted in real world/natural settings<br>• Ship app version updates every ± 2 weeks (ship with tracking) | • *"Translation or commercialisation. Those are intrinsically linked in digital health. A product that's in a state fit to be taken to market, having it translated broadly at a large scale."* (PC22)<br>• *"Depending on the funding and contract, we might be able to scale it up, roll out the app, and do evaluations in real world situations."* (PC2)<br>• *"We did dissemination so we worked with marketers and did a big campaign to release the app. The endpoint is having some commercialised model so that the app can be sustainable."* (PC14)<br>• *"Sometimes we release the beta [app] version. So all beta users get it a couple of days earlier on Android at least, because you can do that with Android…"* (PC29)<br>• *"Sometimes we licence the app to third parties."* (PC2) | | |
| **Publications (Academia/Research)** | • Data analysis, write up and publish academic papers<br>• Reporting on the project process and app product (failures, successes and lessons learnt) | • *"Then there was analysis of the trial and follow-up study findings, and then write up and reporting."* (PC15)<br>• *"Dissemination of the information, so we don't just keep the information to ourselves, so others can learn from our errors and successes."* (PC26)<br>• *"We did some work on publications. We looked at what could we actually do in terms of publications and finding answers to what we set out to try and answer, and find was this app actually able to improve physical activity, what type of user engagement did we have, etc."* (PC16) | PC4, PC5, PC6, PC14, PC15, PC16, PC19, PC20, PC23, PC25, PC26 | Craig, et al. (2008); Mummah, et al. (2016); Ford, et al. (2019); O'Cathain, et al. (2020); Jake-Schoffman and McVay (2020). |
| **Post-Release Market Maintenance and Continuous Improvements (Academia/Research and Industry)** | • Monitoring and maintenance<br>• Continuous user feedback and issue tracking<br>• Customer support<br>• Data and usage analytics<br>• Continuous improvements and updates and bug fixes<br>• Check alignment between app product and the KPIs and the company strategy and goals | • *"We have several different types of tracking in place for the app. We have tracking called feature usage, so we see how users are interacting with the app features and where they are tapping, going back and forth with the screens, for example. We also track interaction, meaning like the users are opening the app, the app sessions, how much time they spending on each app session. We track all of their physical activities, we track what the users are doing, like running distance, the pace and everything. The data team does that."* (PC3)<br>• *"Depending on the contract and who has funded the project, they'll take over the ongoing monitoring. Sometimes we've licenced the projects and apps to third parties…"* (PC2)<br>• *"…keeping things up-to-date, keep them refined, keep improving things. So academics working parallels with actual industry, a company and industry where you're continuing to make, develop and maintain the app product."* (PC22)<br>• *"…we will see if there are any crashes, for example, or user complaints…"* (PC29)<br>• *"We keeping a look on the KPIs and see if it's actually moving the way we expected, and also the different touch points in general, like the company goals."* (PC3) | PC1, PC2, PC3, PC8, PC9, PC10, PC12, PC14, PC22, PC26, PC28, PC29, PC30, PC31 | Craig, et al. (2008); Whittaker, et al. (2012); Blanson Henkemans, et al. (2015); Mummah, et al. (2016); Wilson, et al. (2018); Arigo, et al. (2019); Blandford (2019b); Ford, et al. (2019); Jake-Schoffman and McVay (2020); Sucala, et al. (2020). |

#### 9.3.4.3 The Nature of the Interdisciplinary Process

All of the participants, both in academia/research and industry/commercial practice, discussed the iterative nature of the interdisciplinary collaborative process. *"It's an iterative design process… an iterative development process"* (PC22). *"There's a lot of iterations in the process"* (PC30). PC10 expressed *"…cycling through the process with feedback… typically that's a heck of a lot of times we go through that"*. As for the number of iterations, PC18 explained, *"It's an iterative process. It can have two or maybe even up to five or six iteration cycles or feedback loops"*. This notion was also expressed by PC1, who described *"circling back several times, like one, two, three ideas, building the prototypes and then testing"*, and PC11, who explained *"multiple times, multiple times until you're actually satisfied*".

The number of iteration cycles is often dependant on the time and funding available (Blandford, et al., 2018; 2019b), particularly with academic and research projects, where resources are, more often than not, limited (Liu, et al., 2019; Guo, et al., 2020). Funding and time constraints were voiced by several participants. For instance, PC21 said *"…within some of the [mHealth app] projects, there's a limited period of time and number of iterations that are possible"*, and PC20 expressed *"You're always short on money and time… [and] then the process must be cut short and you won't be able to be as iterative as you'd like"*.

Moreover, for academics/researchers collaborating with industry and commercial software or app development companies, the number of iteration cycles is reduced by funding constraints. PC28 shared, *"If you are working with a company or a separate entity on the technology and app elements, as kind of a service provider, you're also limited by what you can do there because there are only so many times you can go back to them with changes… unless you keep paying and paying and paying"*. PC7 echoed these sentiments, *"If we outsource the development of the [physical activity] app to a company, they have rules with how many changes they can make. Ideally, I would make the process quite iterative until the evaluation phase, but given logistic constraints, sometimes that's not feasible"*.

Along with the iterative nature of the interdisciplinary process, all participants recognised the process as assuming somewhat a linear, albeit flexible and adaptable, nature. Linearity refers to the general progression forward through the process steps, although iteration cycles and feedback loops between various process steps are regular practice (Van Amstel, et al., 2017; Hermsen, et al., 2020). PC2, who practices primarily in academia/research, explained *"It's linear in that there's kind of a set of steps that we need to go through, but especially when it*

*comes to a design and development perspective, we try and make it iterative because you're constantly getting feedback and improving"*. Similarly, PC1, who practices solely in industry/commercial practice, said *"Yeah, it's kind of linear because there are some steps on the way [of the process] that already may be more predefined… but that doesn't mean that we don't circle back in each or any of these phases, because we do often"*. PC15 voiced *"Linear is probably a pretty good description for the process… but also the process is a circular process, like iterative design, development, testing, redevelopment, retesting"*. PC11 described *"You kind of move forward in the process, it's like a straight line, but with lots of round circles, so you go around and around, but then you're still moving in a forward manner"*. These notions were shared by others. *"There's an overall degree of toing and froing, a degree of flexibility and agility… but there's also an overall kind of linear structure"* (PC13), and the process *"…is continuous… is very linear, but very agile and incremental"* (PC16).

Through participants' responses, it was apparent that while iterations can take place at any stage of the process, cycles and feedback loops tend to be more common and rapid within the design, development and testing phase, otherwise referred to as the prototyping stage. This process practice was described by participants in both academia and industry. PC12 explained, *"It's kind of like many circles within that bigger phase"*. In addition, depending on the project and team, some process steps or activities may run in parallel. PC12 described cycling back to an earlier stage of the process to address an unanticipated issue with one of the project's external stakeholders, whilst simultaneously continuing with the design and development.

On the topic of external stakeholders, as discussed earlier in Subsection 9.3.3.4, 58% of the participants expressed the importance of adopting a collaborative co-design or participatory design process, in which case end users are regarded as having *"direct"* involvement in the project (refer to Figure 9.4) and would form part of the project stakeholder group. PC22 said *"Fundamentally, I think co-design is really important"*, and PC15 stated, *"Ideally, it would be more of like a participatory co-design process. Yeah, like active [end user] participation from the get go"*. Unlike PC15, PC2 distinguished between a participatory design process and a co-design process, explaining that a *"…really full, proper co-design process"* requires substantial funding, resources and time, and elaborated that *"it took about 18 months to get through the [design and development] process"* alone. A participatory design process, in comparison, allows for end user feedback and input, but not full end user collaborative design, and therefore *"normally gives [the team] a bit more control of what we're delivering and developing, and we're building on previous learnings and stuff that we've done before"* (PC2).

In contrast, some participants discussed the role of end users as having *"indirect"* involvement in mHealth app projects (refer to Figure 9.4). In this instance, end users do not form part of the project stakeholder group, and are generally involved as participants at particular stages of the project process. Indirect end user involvement allows the project team to maintain more control over the direction of the mHealth physical activity behaviour change intervention app solution and final product design. It also allows the project team to test specific theories, BCTs, PSD principles, or components of a given app. PC27 said *"We made a conscious decision to not include end users from the start,"* because *"...we wanted to test the content, BCTs and theories that informed… the intervention. And we didn't want them [end users] to change the content"*.

Regardless of whether a project team chooses to adopt a co-design or participatory design approach, or not, the nature of the interdisciplinary collaborative process will be influenced. For instance, as quoted above, PC2 explained that adopting a *"…really full, proper co-design process… it took about 18 months to get through the [design and development] process"* alone. Whereas PC27, for example, explained that the interdisciplinary team was limited to a short timeframe, in which case they *"made a conscious decision not to include end users from the start"* and to rather dedicate *"the first four months to really intensely developing the toolkit"*. These team decisions have an impact on the nature of the interdisciplinary collaborative process, and also impact on the final mHealth physical activity app product. A summary of the terms describing the nature of the interdisciplinary process is provided in Figure 9.5.

The nature of the interdisciplinary process is also impacted by the collaborations between academia and industry. In the interdisciplinary digital health and mHealth app field, academic-industry collaborations play a critical role in advancing health behavioural science into real world practice (Ford, et al., 2019; 2021; Sucala, et al., 2021) and there is "a growing interest in refining collaborative processes between academia and industry" (Ford, 2020, p.11). Academic-industry collaborations are argued to provide opportunities for rapid research and digital health innovation, while meeting the needs of the quickly evolving technological climate (Arigo, et al., 2019; Ford, et al., 2021). Challenges, however, arise due to the conflicting timelines and priorities between academia and industry (Arigo, et al., 2019; Liu, et al., 2019; Ford, et al., 2021). These challenges influence the process in terms of project and team formation; funding and investment; formative research; design and development; formative testing; implementation; summative evaluation; commercialisation and consumer app market release; and continuous improvements (Arigo, et al., 2019; Ford, et al., 2021; Sucala, et al., 2021). For the mHealth behaviour change intervention app arena to progress further there is a

need to develop more robust academic-industry collaborations, improve evidence-based and ethical practices for promoting (physical activity) behaviour, and to advance common process practices and work procedures between academia and industry (Arigo, et al., 2019; Liu, et al., 2019; Ford, et al., 2021). These points were echoed by PC28, who expressed *"We [academics/researchers] need better collaboration with industry. It would make sense for us just to work together rather than working against each other in a sense, you know"*.

### 9.3.5 Main Theme 5: Objects and Supporting Artefacts

Objects and supporting artefacts represents the fifth main thematic finding of the interview study. This fifth theme corresponds to the proposed Interdisciplinary mHealth App Design Framework's third theme (namely *"Main Component 3: Boundary Objects and Supporting Artefacts"*) (Chapter 7, Section 7.5). The objects and supporting artefacts theme can be divided into nine subthemes: (1) *project management and interdisciplinary team communication objects*, (2) *problem and conceptual solution objects*, (3) *design, development and formative testing objects*, (4) *intervention content and app design feature objects*, (5) *implementation, evaluation and study objects*, (6) *post-release market surveillance objects*, (7) *supporting methods*, (8) *standards and guidelines*, and (9) *supporting materials*. Figure 9.7 provides a diagrammatic summary illustration of the key theme and subthemes for objects and supporting artefacts; discussed in the subsections below.

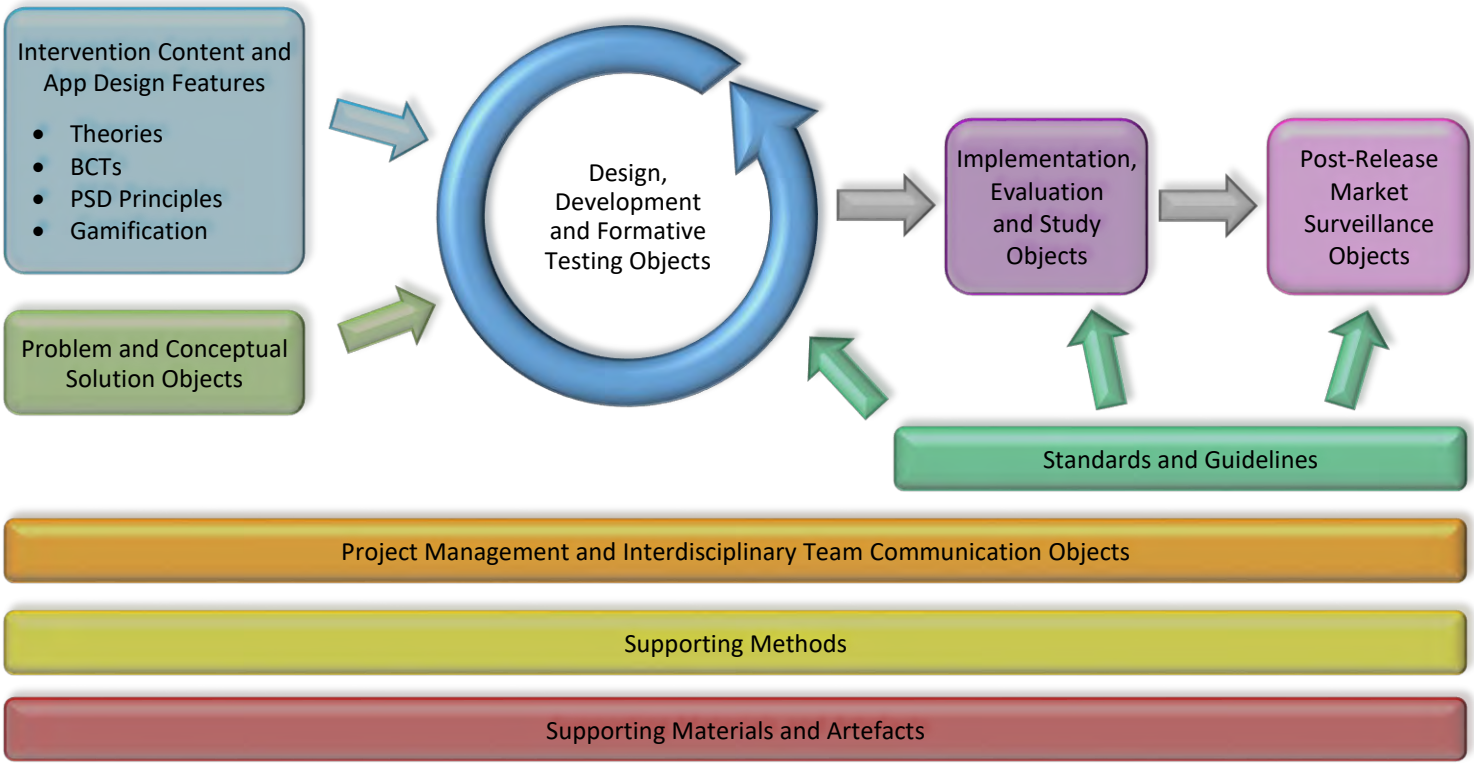



*Figure 9. 7: Objects and Supporting Artefacts (Main Theme 5): Interview Study Findings [Source: Researcher's own construction]*

#### 9.3.5.1 Project Management and Interdisciplinary Team Communication Objects

Project management and effective interdisciplinary team communication are essential to the success of mHealth physical activity behaviour change intervention app projects. As illustrated in Figure 9.7, project and team management objects (the orange elongated rectangle) provide a cross-thematic foundation for the mHealth physical activity behaviour change intervention app project process. All 31 participants stressed the important role of project managers and principal investigators in guiding the interdisciplinary collaborating team through the process of designing, developing and evaluating mHealth physical activity intervention apps. The participants' notion that good project management leads to "better quality results" is echoed in the WHO's *mHealth: New Horizons for Health Through Mobile Technologies* report (WHO, 2011, p.7), the *Monitoring and Evaluating Digital Health Interventions* guidelines (WHO, 2016), and the *Be He@lthy Be Mobile* handbook (WHO, 2020g). In addition, participants repeatedly stressed the importance of effective and efficient communication between heterogeneous collaborating team members throughout the project lifespan. PC1 accentuated *"Ultimately, it boils down to communication throughout the process"*, while PC15 expressed that *"keeping the channels of communication open is really important"*, and PC19 highlighted *"it's all about communication"*. PC24 also emphasised that *"really good communication skills are truly valuable in multi-paradigmatic [interdisciplinary] projects, like apps for changing peoples' physical activity behaviour"*.

Project management tools are useful for planning, organising and tracking activities and tasks throughout mHealth intervention projects, and team communication and collaboration software is helpful in supporting interdisciplinary teamwork (Davies and Mueller, 2020). PC27, for instance, emphasised the importance of *"establish[ing] very clear management tools and project tools from the get-go"*. For mHealth intervention projects specifically, Davies and Mueller (2020) provide a list of project and team management software/tools, including Slack, Trello, Microsoft Teams, and Asana. These tools, in addition to other software/tools, where frequently mentioned by participants. Table 9.5 outlines several project and team management software/tools that participants identified having used in their past and current mHealth physical activity behaviour change intervention app projects, along with quoted descriptions (provided by participants), participant codes (PC) for who mentioned each tool, and the URLs for each tool.

*Table 9. 5: Project and Team Management Software/Tools: Interview Study Findings*
*[Source: Researcher's own construction]*

| Project Management Software/Tool | Project Management Software/Tool Description *(if provided by participants)* | PC Evidence | Project Management Software/Tool URL |
|---|---|---|---|
| **Slack** | • *"Slack as a tool where we chat with each other in like different groups, project groups, but also the different teams, so lots of different channels in there."* (PC1)<br>• *"…different channels for, ask the data, ask the design or topic user research on certain different topic related channels, and then some people share insights, they share results. They share the KPIs, the company goals, all sorts of stuff."* (PC3) | PC1, PC3, PC14, PC22, PC27, PC28, PC29 | https://slack.com/intl/en-za/ |
| **Trello** | • *"Trello was one of the main programs that we use (sic) for project management. And so in this Trello, we had all the project management process and we were able to share with the different members in the team. It was very useful for the project."* (PC5)<br>• *"We used Trello…"* (PC7)<br>• *"We've used Trello… yeah we've used Trello in the past for some kind of project management tasks…"* (PC22) | PC2, PC5, PC7, PC22 | https://trello.com/en |
| **Microsoft Teams** | • *"Actually MS Teams more recently has been quite effective in collaborating and chatting about stuff and sharing documents. In MS Teams there's a planner feature, and you can set deadlines and stuff like that"* (PC28) | PC2, PC5, PC11, PC15, PC18, PC19, PC20, PC26, PC28 | https://www.microsoft.com/en-za/microsoft-teams/log-in |
| **Asana** | • *"Asana was actually the main platform we used. One of the tools we used for the purpose of managing and leading the team. That's where we had tasks set up for the team, and where the team could follow-up; all the project stuff happened in Asana"* (PC12)<br>• *"We used project management software. Asana. Yeah we used that, and it was useful for working in teams, and we could manage progress, assign tasks to people"* (PC28) | PC11, PC12, PC28 | https://asana.com/ |
| **Basecamp** | • *"We used Basecamp for a couple of projects."* (PC20)<br>• *"Basecamp was the official channel we used…"* (PC21)<br>• *"We used a project management tool called Basecamp."* (PC27) | PC20, PC21, PC27 | https://basecamp.com/ |
| **Monday** | • *"Monday.com is a project management tool where you can manage tasks, team work and projects in general, and also track deadlines. You can also record and monitor activities in there, and plan team work and version iterations of the app and app prototypes."* (PC11) | PC11 | https://monday.com/ |
| **Confluence** | • *"Confluence for documenting, and really putting different documents together, that are then finalised so to say, and having the roadmap also in there."* (PC1)<br>• *"We used Confluence with the research team, because they were leading the testing and things like that…"* (PC12) | PC1, PC12, PC13, PC26 | https://www.atlassian.com/software/confluence |
| **Jira** | • *"Jira, our task management tool…."* (PC1)<br>• *"We use Jira to track all the user stories and manage project scope, but in an agile way. So we have user stories, things that the team is going to work on in sprints, and task breakdowns."* (PC3)<br>• *"We use Jira wiki… we have all the documentation related to the company, to the projects and areas…"* (PC3)<br>• *"Wiki integrates with Jira. Wiki, that's mainly used for documentation, meeting notes and process documentation and so on… the Jira wiki is just for sharing static information."* (PC29)<br>• *"We use Jira to talk to the developers and designers to really try and make sure that we're understanding each other. So the follow up of every session, then we'd put it all on Jira to try and explain everything in real simple language…"* (PC26) | PC2, PC3, PC12, PC13, PC26, PC29 | https://www.atlassian.com/software/jira |
| **Microsoft Project Management** | • *"Yeah, so project management tool, there's a Microsoft Project Management version…"* (PC13) | PC13 | https://www.microsoft.com/en-za/microsoft-365/project/project-management-software |

Along with the above-mentioned project and team management software/tools, some participants also specified using Google Business Suite (PC1, PC3, PC26, PC29), Collaborate (PC15), Google Calendar (PC11, PC29), Obsidian (PC22), Google Poll (PC5), Microsoft Stream (PC18), Google Sheets (PC28, PC29), and PBworks (PC26). Microsoft Word, Excel, PowerPoint, To-Do Lists, and OneNote were also mentioned by over half of the participants (PC4, PC7, PC9, PC10, PC11, PC12, PC16, PC18, PC19, PC20, PC21, PC22, PC26, PC27, PC28, PC29). Furthermore, all 31 participants identified a handful of tools and platforms used to support the interdisciplinary team's communication and collaboration. These tools and platforms include video and teleconferencing technology, instant messaging apps, and other electronic and networking technology. Participants also described using these tools and platforms more frequently since the global outbreak of the novel severe acute respiratory syndrome coronavirus 2 (COVID-19) pandemic. The increased usage and reliance on such technologies, owing to the COVID-19 pandemic, has been regularly reported in literature (Hacker, et al., 2020; Vargo, et al., 2020). Table 9.6 outlines the communication tools and platforms, along with the participant codes (PC) for who mentioned each tool/platform, and the URLs if available.

*Table 9. 6: Interdisciplinary Team Communication Tools and Platforms: Interview Study Findings [Source: Researcher's own construction]*

| Communication Tool/ Platform | PC Evidence | Communication Tool/ Platform URL |
|---|---|---|
| **WhatsApp** | PC28 | https://www.whatsapp.com/?lang=en |
| **Zoom** | PC2, PC4, PC5, PC9, PC10, PC11, PC12, PC15, PC18, PC19, PC22, PC27, PC28 | https://zoom.us/ |
| **Skype Personal/Skype for Business** | PC4, PC9, PC13, PC16, PC18, PC21, PC22, PC27 | https://www.skype.com/en/ |
| **Cisco Webex** | PC4, | https://www.webex.com/ |
| **Google Meet** | PC3, PC29 | https://meet.google.com/ |
| **Google Hangouts** | PC9, PC28 | https://hangouts.google.com/ |
| **Facebook Messenger** | PC14 | https://www.messenger.com/ |
| **Email** | PC1, PC2, PC3, PC4, PC6, PC10, PC11, PC12, PC13, PC14, PC16, PC17, PC19, PC21, PC22, PC27, PC29 | - |
| **Phone Calls (with and without video chats, one-on-one, group)** | PC1, PC10, PC12, PC13, PC18, PC21, PC22, PC28 | - |
| **Text Messaging** | PC18, PC28 | - |

In addition to the project and team management software/tools, and the interdisciplinary team communication tools/platforms, several participants identified a variety of other objects relevant to project and team management. These included: a project plan (PC16, PC26); a project management plan (PC16, PC26); a team contract (PC27); meeting agendas and meeting minutes (PC16); a project dissemination plan (PC26); a stakeholder engagement strategy and plan (PC26); a team management plan and timeline (PC27); and a project budget plan (PC9). Some of these objects, such as the project management plan, is identified in the WHO's *mHealth: New Horizons for Health Through Mobile Technologies* report (WHO, 2011). One participant, PC27, also emphasised the importance of the project and team contract, referring to it metaphorically as a *"prenup"*. They explained that *"...the most important thing, particularly with project and team planning, is to be very clear on the prenup, so you know that this person does this, this and this, and that person does that, that and that. And if I do this, don't ask me to do that"* (PC27). Essentially, PC27 was describing the importance of good team member and resource task allocation and planning, and the fundamental role it plays in ensuring project success. Later on, PC27 reiterated *"the prenup, the contract, needs to be done from the start, and has to be very well discussed by the team to provide a good structure and fundamental things for the project and team, so that everyone knows what to do and work on"*.

In addition to these above-mentioned objects, a few participants discussed using presentation and slide deck software/tools, including Prezi (PC18), Mentimeter (PC26), Google Slides (PC1, PC3, PC29), SharePoint (PC26), and SlideShare (PC18). Added to this was the mention of several cloud services, including Google Drive, Google Docs, Dropbox and OneDrive (PC1, PC4, PC9, PC12, PC18, PC22, PC26, PC27, PC28). Moreover, some participants mentioned diagramming tools and discussed the use of diagrams to support project and team communication and collaboration efforts. These included: Gantt charts (PC4, PC18, PC22); project timelines (PC4, PC9, PC11, PC13, PC22, PC26, PC27); flow charts, using App.Diagrams.net (PC26); mind maps, using Coggle (PC26); the Sankey diagram (PC28); and various other diagrams (PC4, PC26, PC27, PC28).

Project, team and process documentation was frequently reported as critical to the success of mHealth physical activity behaviour change intervention app projects. PC13 emphasised *"the documentation is really critical"*, especially considering it provides a means of tracking decisions and rationale throughout the project process, and allows team members to back-reference any important details pertaining to the project, team and process, such as project

requirements, team member role responsibilities, task assignments, and meeting minutes. Some participants discussed the importance of maintaining up-to-date documentation that is easily accessible to all team members (through online cloud services, intranets and project/team software) so that any potential setbacks or challenges do not hinder a project's progression. PC13 stressed, *"In interdisciplinary teams, there needs to be good documentation. If someone leaves, then the documentation and everything needs to be available for someone else to pick up, so the project doesn't just break down because one critical person is not involved anymore"*. Furthermore, for projects primarily conducted in academic/research environments, some participants mentioned objects such as research plans, research project proposals, and research grant applications (PC17), as well as ethics documentation and online ethics application systems (PC4, PC15, P17). In comparison, for projects primarily conducted in industry, participants mentioned objects such as product plans and product briefs (PC3).

Overall, the participants' use of project management and interdisciplinary team communication objects were described by participants as *"waxing and waning"* (PC22). This means that interdisciplinary teams tend to *"generally use one [software/tool] for a while and then move on and try something else"* (PC2), and often it is a matter of *"personal preference"* (PC5). Many participants discussed face-to-face meetings and workshops as effective and efficient, and preferred, methods for good interdisciplinary team communication and collaboration.

#### 9.3.5.2 Problem and Conceptual Solution Objects

Participants identified various objects and artefacts pertaining to the problem and conceptual solution of mHealth physical activity intervention app projects, which can be broken down into two categories, corresponding to three process steps. The *problem objects* correspond to the *"literature and market review"* (second) step and the *"problem understanding and formative research"* (third) step of the interdisciplinary collaborative process (Table 9.4). The *conceptual solution objects* correspond to the *"ideation and conceptualisation"* (fourth) step of the interdisciplinary collaborative process (Table 9.4). As illustrated in Figure 9.7, problem and conceptual solution objects (the left-hand side light green rectangle) provide input into the design and development of a mHealth physical activity behaviour change intervention app.

***Problem Objects***

Participants mentioned a handful of objects relevant to gaining an understanding of the problem space. Literature, primarily from an academic/research perspective, was mentioned by several

participants. PC15 described conducting literature reviews as a means to *"develop a sense of what the problem is, or where the gap is, and what needs to be addressed or solved"*. PC28 discussed the importance of *"gaining insights into the problem [and] what the barriers and challenges are"* and PC2 emphasised *"understand[ing] the problem"* before conceptualising a solution. Conducting a market review can also provide insight into where the gaps are in the current mHealth physical activity consumer app market (PC1, PC11, PC15, PC29). According to some participants (PC1, PC2, PC18, PC29), the output of the problem explication process should result in a problem statement (an object that clearly defines the problem).

***Ideation and Conceptualisation: Objects used within Interdisciplinary Collaborative Teams***

Eight participants (PC3, PC11, PC18, PC20, PC26, PC28, PC30, PC31) mentioned using post-it sticky notes as a quick means of jotting down ideas, and sticking them on whiteboards. Five participants (PC3, PC20, PC27, PC28, PC31) described using whiteboards, both in manual and virtual form, to support the team's ideation and brainstorming process. Miro (PC3, PC29), Doodly (PC27), Mural (PC28) and Jamboard (PC29) were named as online virtual whiteboard team collaboration tools used for ideation and brainstorming sessions. PC3 described Miro as *"…a really good tool. It's an infinite canvas, so the team can do whatever they want. There are no limits to imagination. So we used Miro when we want to brainstorm some ideas, and it's easy because it runs well in the browser, and you can have post-its there too, and you can even have a voting system and put timers, and you don't need to install anything. So it's really nice for the team to work together and brainstorm and be creative coming up with ideas"*.

Workshops and brainstorming sessions, both in-person and virtual, were mentioned by many participants, as creative and collaborative ways of generating ideas within the team. The virtual ideation/conceptualisation workshops and brainstorming sessions were described as being supported by videoconferencing technologies such as Zoom and Microsoft Teams. Another participant spoke about formulating ideas by *"…writing down your concepts, colour mapping and colour coding to bring concepts together"* (PC11). Microsoft Visio and other mind mapping software was also mentioned as useful for generating ideas within the team.

***Formative Research, Ideation and Conceptualisation Objects with External Stakeholders***

When adopting a co-design, participatory design or design thinking process, participants spoke about carrying out formative research, ideation and conceptualisation activities with external stakeholders, primarily end user representatives of the intended target audience, but also with

other external project stakeholders such as project funders and investors, the project steering committee(s), and government/departmental partners. In light of the COVID-19 pandemic, many participants described using videoconferencing technology such as Zoom (PC10, PC11), Google Meet (PC3), Google Polls (PC5) and UserZoom (PC1) with end user representatives for formative research and ideation brainstorming. Videoconferencing technology was also described as being used in cases where the intended target audience was dispersed across different geographical locations. Moreover, some participants discussed conducting a needs analysis with end user representatives, and producing a needs assessment report as valuable objects for better understanding the problem space and generating possible ideas and solutions.

#### 9.3.5.3 Design, Development and Formative Testing Objects

Participants identified an extensive range of objects and artefacts relevant to the iterative design, development and formative testing stage of mHealth physical activity behaviour change intervention app projects. The objects and artefacts discussed in this subsection correspond to the fifth *"iterative design, development and testing"* step of the interdisciplinary collaborative process (Table 9.4). Figure 9.7 illustrates design, development and formative testing objects as integral to the iterative cycle (the dark blue cycle). The object and artefact findings from the interview study are categorised into (1) *design*, (2) *development*, (3) *formative testing*, (4) *connecting devices and branding*, and (5) *quality assurance*.

***Design***

As discussed in Chapter 4 (Sections 4.4.1 and 4.4.3), designing mHealth physical activity intervention apps fundamentally involves a consideration for two perspectives, namely a health behavioural sciences versus an information systems perspective (Sullivan and Lachman, 2017; Blandford, et al., 2018). Quintessentially, these two perspectives concern the health behaviour change intervention (and its components and BCTs) and the software design features of the app (and its acceptance, usability, user experience and persuasiveness), respectively. Several participants confirmed the importance of both sides. PC7 explained *"Yeah, the content and how to communicate that content with the user versus how to engage the user with that content. That's the two components we look at. The one part is the intervention itself, and what theories and techniques we incorporate in the intervention to encourage people to be more [physically] active, and the other part is how to make the app appealing for use beyond the intervention. So how do we get it [the app] to be appealing and get users to continue engaging beyond that first time use, that's a different issue than just putting behaviour change content in there"*.

Participants identified a number of different objects relevant to the design of both the intervention and app features. On the one hand, participants mentioned various prototypes that they, as an interdisciplinary collaborating team, iteratively create and refine, which essentially means these prototypes function as design boundary objects (presented in Chapters 5 and 7). On the other hand, participants named a few software tools that interdisciplinary teams typically utilise to support the collaborative design of these prototypes. Table 9.7 pinpoints the various prototypes (low, medium and high fidelity), design objects and design software tools; quoted descriptions of each object (if provided by participants); participant codes (PCs) for those who explicitly mentioned each object; and mHealth physical activity app literature that supports the identified objects (if available) or the URL links to design software tools.

*Table 9. 7: Design Objects and Software Tools: Interview Study Findings [Source: Researcher's own construction]*

| **Design Object/ Software Tool** | **Description of Design Object/Software Tool** *(if provided by participants)* | **PC Evidence** | **Literature Support or Software URL** |
|---|---|---|---|
| ***Intervention Design*** | | | |
| **Logic Models** | • *"We create a logical driver diagram to work through what are the outcomes we're trying to achieve. What are the behaviour constructs we're using? What are the things that we're really trying to change? What behaviours are we trying to change, like physical activity? How are we going to do that? So we do a simple logic diagram."* (PC2)<br>• *"We create logic models of the intervention to see the effects."* (PC20) | PC2, PC20, PC21, PC27, PC28 | Bartholomew Eldredge, et al. (2016); Direito, et al. (2018); Sucala, et al. (2020). |
| **Use Cases** | • *"We pull key things that might be actionable to implement in the intervention and then we would kind of develop use cases around that."* (PC21)<br>• *"We create some kind of usage scenarios, for example, a physical activity app, trying to imagine all the steps that a user may go through and in different scenarios. For example, if it's bad weather or if to go for a run or a walk. Try to go through these scenarios with people and try to develop new scenarios, to kind of get the requirements, aspects of what we should be developing, that should be focused on."* (PC31) | PC21, PC31 | Vaquero (2016); Monteiro-Guerra, et al (2020); Sucala, et al. (2020; 2021). |
| **Information Flows/ Data Flows** | • *"Data flows is another important one. This is to see where the gaps are, where we're not collecting certain data and information points, or where we're repeating data and information points, so like an information flow."* (PC26) | PC26 | Direito, et al. (2018); Davies and Mueller (2020). |
| **Process Flows** | • *"…using a Sankey diagram because it shows flow, process flow, which is important to see…"* (PC28) | PC28 | Direito, et al. (2018). |
| **Physical Activity Plans** | • *"…training plans in the app…"* (PC3)<br>• *"…including general healthy lifestyle guidelines in the app…"* (PC27)<br>• *"…exercise plans or exercise programs…"* (PC23)<br>• *"…strength training plans and workouts to follow…"* (PC29) | PC1, PC3, PC23, PC27, PC29 | Modave, et al. (2015); Aslam, et al. (2020); Monteiro-Guerra, et al (2020). |
| ***App Design and App Prototypes*** | | | |
| **Use Cases** | • *"We create use case scenarios to envisage the flow charts, like 'if the user clicks this button, this will happen', and we'll have boxes and arrows, and flowcharts are translated into scenarios for the technology team."* (PC21) | PC21 | Vaquero (2016); Monteiro-Guerra, et al. (2017). |

| | | | |
|---|---|---|---|
| **Design Cards** | • *"Sometimes we've used some design cards…"* (PC24) | PC24 | - |
| **Storyboards** | • *"…we will probably produce some like wireframes, storyboards and sketches of how we want it to look…"* (PC28)<br>• *"…we'll have like app screen flows…"* (PC3)<br>• *"So because we develop storyboards of each session, so that our, our content was kind of divided in 18 sessions around that, so people will have access to 18 sessions, and we had the storyboards for each one of them."* (PC27) | PC3, PC5, PC16, PC25, PC27, PC28, PC30 | Wilson, et al. (2018); Honary, et al. (2019) |
| **User Flows/ User Journeys** | • *"…presented flows, like these flows or user journeys…"* (PC1)<br>• *"We also use like user flows… and like user journey flow through the different app screens, yeah."* (PC20) | PC1, PC2, PC3, PC5, PC16, PC20, PC25, PC26, PC27 | Sucala, et al. (2020). |
| **Wireframes** | • *"…make some wireframes, so low fidelity prototypes…"* (PC24)<br>• *"…we will probably produce some like wireframes…"* (PC28)<br>• *"…first wireframes…"* (PC1) | PC1, PC2, PC13, PC24, PC27, PC28 | Wilson, et al. (2018); Monteiro-Guerra, et al (2020); Sucala, et al. (2020). |
| **Low Fidelity Paper Prototypes** | • *"…usually sketches done on paper…"* (PC1)<br>• *'…pen and paper sketches initially, and then working with the design team to refine them."* (PC10)<br>• *"…those initial sketches where it's pen and paper, like static pictures and images…"* (PC10)<br>• *"…sketches of how we want it to look…"* (PC28)<br>• *"…I had a paper prototype, like cardboard paper with drawing on…"* (PC18) | PC1, PC5, PC10, PC14, PC18, PC20, PC28 | Ben-Zeev, et al. (2015); Monteiro-Guerra, et al (2020); Sucala, et al. (2020). |
| **Mock-Ups** | • *"We'll do screen mock-ups…"* (PC1)<br>• *"Mock-ups of how the app's front end aesthetic would look…"* (PC10)<br>• *"We had mock-ups of the exercise games in the app and the different kind of screens a user would see, and different versions of what it looked like, and we'd check it for look and feel and user experience before it was implemented and developed."* (PC21)<br>• *"…so like mock-ups of the app screens and stuff…"* (PC28) | PC1, PC3, PC10, PC20, PC21, PC22, PC26, PC27, PC28, PC31 | Schnall, et al. (2016); Harder, et al. (2017); Martin, et al. (2020); Monteiro-Guerra, et al (2020). |
| **User Interface Screen Designs** | • *"From a design perspective, like producing app interface screens."* (PC1)<br>• *"Figma, a design tool, where you can prototype app screens…"* (PC29)<br>• *"…we had screen designs, and storyboards with screen designs."* (PC5)<br>• *"…app screen designs and descriptions around them…then screen designs into final UI designs…"* (PC1) | PC1, PC2, PC3, PC5, PC7, PC20, PC25, PC26, PC28, PC30, PC31 | Schnall, et al. (2016); Harder, et al. (2017); Monteiro-Guerra, et al (2020). |
| **Usability/UX Flows** | • *"…my colleague did the usability, usability (sic) flows…"* (PC26) | PC3, PC26 | Harder, et al. (2017). |
| **Minimum Viable Product** | • *"It's usually useful to kind of define the minimum viable product. So what is the absolutely the (sic) minimum set of requirements and get that done first, and then go from there" (PC20). "What's also really useful is having and using a core outcome set" (PC21).* | PC21 | Ben-Zeev, et al. (2015); Davies and Mueller (2020). |
| **Medium Fidelity Prototypes** | • *"…mid fidelity would be InVision because you make the different screens and features of the physical activity app are touch interactive, so the user can see pop ups and can feel user experience, even though they are only pretending to use the app…"* (PC18) | PC10, PC14, PC18 | Bartlett, Webb and Hawley (2017). |
| **High Fidelity Prototypes** | • *"…sometimes we just went straight into doing our high fidelity prototypes…"* (PC12)<br>• *"…then we've gone into sort of like high fidelity… a high fidelity prototype app, the version of the app that's actually working…"* (PC14)<br>• *"…then obviously we went to the high fidelity to test it…"* (PC16)<br>• *"…did high fidelity and that was working, fully functional…"* (PC18) | PC1, PC2, PC3, PC5, PC9, PC10, PC12, PC13, PC14, PC16, PC18, PC24, PC26, PC29, PC30 | Ben-Zeev, et al. (2015); Sucala, et al. (2020). |

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|---|---|---|---|
| **Alpha App** | • *"…alpha app version for alpha testing with the team…"* (PC14) | PC14 | Wilson, et al. (2018); Davies and Mueller (2020); Nicholas, et al. (2021). |
| **Beta App** | • *"…beta version…"* (PC26)<br>• *"…beta delivering…beta app version"* (PC9)<br>• *"…beta app version for beta testing…"* (PC10)<br>• *"…beta testing with the beta app version…"* (PC28)<br>• *"So usually, we release the beta app version, so all beta users get it a couple of days earlier, on Android at least…"* (PC29) | PC9, PC10, PC14, PC26, PC27, PC28, PC29 | Francis (2017); Wilson, et al. (2018); Davies and Mueller (2020); Sucala, et al. (2020); Nicholas, et al. (2021). |
| ***App Design Software and Tools*** | | | |
| **Microsoft PowerPoint** | • *"…you can hyperlink objects to different slides. I could set my designs up so that when it was in presentation mode. You could be clicking on buttons [and] you could try and set it up so that you'd show people… and feel like they're navigating through the app screens, like they're actually navigating the design. I found that really helpful for, partly for visualizing it in my head, but one of the things that turned out to be really valuable was figuring out problems with your app flow structure and navigation."* (PC22) | PC20, PC22 | https://www.microsoft.com/en-za/microsoft-365/powerpoint<br><br>Schnall, et al. (2016). |
| **Tablets** | • *"So, to do the designs and stuff, some people use iPads, for example, or other tablets where they can do digital designs on…"* (PC3) | PC1, PC3 | Aslam, et al. (2020). |
| **Clipart** | • *"…is such a useful thing to use to see how things could look…"* (PC11) | PC11 | https://www.clipart.com/ |
| **Paint** | • *"…some simple tools like paint..."* (PC13) | PC13 | https://canvaspaint.org/ |
| **Diagrams. Net/ Draw.io** | • *"…there's a tool I use for flow charts within the app. It's https:app.diagrams.net/". It's such a great little program…"* (PC26)<br>• *"…I used Draw.io for mid-fidelity app prototypes…"* (PC18)<br>• *[App.Diagrams.net was formerly Draw.io]* | PC18, PC26 | https://app.diagrams.net/ |
| **Justinmind** | • *"I've tried an application called Justinmind before, a prototyping and wireframing tool…"* (PC26) | PC22 | https://www.justinmind.com/ |
| **Adobe** | • *"I also very frequently will use Adobe Photoshop or InDesign…"* (PC22)<br>• *"When I was designing it, I was using Adobe Illustrator…"* (PC16)<br>• *"Recently I'm starting (sic) to try and teach myself how to use Adobe Illustrator for design work."* (PC22)<br>• *"…then there's one from Adobe, I think it's called Adobe XD, it's a kind of UX tool from Adobe."* (PC31)<br>• *"Prototyping software like InDesign or other open source software"* (PC31) | PC16, PC22, PC31 | https://www.adobe.com/africa/creativecloud.html |
| **Balsamiq** | • *"We use sometimes Balsamiq for low fidelity stuff…"* (PC1)<br>• *"So then we use Balsamiq especially when it's like totally new concepts, then we also use like low fidelity mock-ups."* (PC1)<br>• *"…we used Balsamiq for low- to mid-fidelity prototypes."* (PC18)<br>• *"For lo-fi prototypes, or wireframes, we'd use Balsamiq."* (PC24) | PC1, PC18, PC24 | https://balsamiq.com/ |
| **PSDM Tables** | • *"Normally what I do it just take the four PSD tables, you know they have all of the persuasive design features in the four categories..."* (PC24) | PC24 | Oinas-Kukkonen and Harjumaa (2009) |
| **Proto.io** | • *"Then we've used Proto.to. It's pretty nice looking prototypes and you can even add interactivity there, it's for Android and iOS."* (PC20) | PC20 | https://proto.io/ Monteiro-Guerra, et al (2020). |
| **POP** | • *"We also used POP. It was very nice, POP. Yes it was quite nice to develop a functional prototype"* | PC20 | https://marvelapp.com/pop |
| **InVision** | • *"We used InVision, it allows for mid-fidelity prototypes…"* (PC18) | PC18 | https://www.invisionapp.com/ |

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|---|---|---|---|
| **Figma** | • *"For design we use Figma as a design tool, so then all the app screen designs are always in there to be found. Also, the flows and usually descriptions around them. Many comments and interactions are also happening in there [Figma]. And then they are also linked back again to the documentation and to the specific user stories, where there's a specific app screen design, for example, is needed and needs to be implemented accordingly."* (PC1)<br>• *"From a design perspective, like producing screens, we use Figma. With this Figma, we do all sorts of things like we do user flows, we do user journeys, screen flows, we create the screen themselves. We use the tool to receive and give feedback. It's a really easy and good collaborative tool."* (PC3)<br>• *"Once we have the final designs, it stays on this Figma file and everything's there. Wwe have specifications in a sense of font style, font size, spacing, measurement of the elements, everything needed for development."* (PC3)<br>• *"Fimga, it is a design tool where you can prototype screens. We can create a prototype that you can deploy on a phone so that you can really use it like a fake app, basically, that's used for collaborating on screen designs across the design team, but also to share it with the team, for example, where you can also see the specifications. And it can also be used for quantitative prototyping prototype testing."* (PC3) | PC1, PC3, PC29, PC31 | https://www.figma.com/ |

***Development***

Developers (actors identified in Table 9.2) are generally responsible for coding and programming mHealth physical activity behaviour change intervention apps. Considering the focus of this research project and interview study is on mHealth physical activity consumer apps, several participants discussed the two main smartphone app platforms, namely Apple OS and Android OS. To develop mHealth physical activity apps for Apple devices, participants identified Xcode (PC1, PC3, PC14, PC28, PC29), and for Android devices, participants identified Android Studio (PC1, PC3, PC14, PC18, PC28, PC29). PC29 explained, *"For iOS, it's Xcode. That's the single platform you can use for developing iOS apps. For Android, it's Android Studio"*. As for other related development software, PC29 reported, *"Many developers use Sourcetree, which is a versioning tool, basically it works with Git, Git is a repository basically, where you can have version control over the source code you're checking in. And then on the server side, for the version control system, we're using Stash, it's also an Atlassian product used for pull requests. For example, when developers are checking their source code, and they need to review the source code to make sure that they are meeting the standard of quality. Also people can comment on it, and can change the code until everyone's satisfied and then merge the code in the master branch"*. In addition to these tools, PC18 mentioned using React Native for Android (API). Furthermore, to vectorise drawings and convert them into code, PC1 mentioned PaintCode, *"They [developers] use PaintCode on iOS to add icons to the app and for implementation, so that they're vectorised and stuff"*.

Another participant, PC6, discussed using PhoneGap to develop their app, explaining, *"I used PhoneGap to create an app for iOS. PhoneGap allowed me to create applications for iOS using just JavaScript, HTML and CSS"*. Xamarin, an open-source mobile app platform for .net, was identified by two participants (PC8, PC28), and MvvmCross was also mentioned (PC8). In addition to these tools, other tools reported by participants included LifeGuide (PC23, PC25); GitHub (PC6); Visual Studio (PC6, PC16); JavaScript (PC18); Eclipse (PC13); as well as Java, XAMPP, Apache, PHP, MySQL, CSS and HTML5 (PC6, PC13, PC16, PC27).

Two participants also discussed using content management systems. *"We also used Joomla., which is kind of back office of a website. It allowed us to develop all the contents, and integrate the contents"*, reported PC27. PC5 explained *"We had a content management system, where the people with the health background could go in and fill in the content. For example, if there are texts, or audios that need to be uploaded, we were doing it ourselves… and putting the content inside. I think they're good for independence. For me, as a health professional that doesn't have technical skills, I have to talk to the IT people and say, 'Oh, could you help me with this'. But with the content management system, I kind of felt 'Oh, I'm independent. I'm uploading stuff myself' which was nice"*. Based on PC5's explanation, content management systems can be useful for supporting collaborative work between developers and health professionals, and help bridge the divide between technology and health.

A valuable finding relating to mHealth physical activity behaviour change intervention app development was that a few participants, particularly from health backgrounds, through experience, came to realise the challenges and difficulties faced by developers. PC14 shared, *"I think that's something I've really learned is that developing smartphone apps is really hard. It's really hard to create an app that's robust across so many different devices, especially with Android. People were accessing the app from all these different smartphones and tablets, and when we did usability testing, we'd find the app would work perfectly well on one person's Samsung Galaxy S8 and then somehow not work properly on another person's Galaxy S8. So it's really tricky, and this what I learnt through usability testing, just how finicky the software is across different devices, especially Android"*.

In light of these challenges, it is imperative that professionals from the health side and information systems/technology side communicate and collaborate effectively throughout the mHealth physical activity behaviour change intervention app development process (Sullivan and Lachman, 2017; Blandford, et al., 2018; Sucala, et al., 2020). PC14 said *"It's usually quite*

*collaborative, as someone from the health side, working with developers, because of their expertise. So yeah, working together and working through the [development] process, discussing how the app will be laid out. They'll start developing, send it through to us and we'll see how it's looking and the functionality and stuff, and provide feedback. So just making sure that the content and aesthetics and everything that we're kind of envisaging is in the app".*

***Formative Testing***

Formative testing forms an integral part of the iterative design, development and testing process (Othman, Ugap and Rahman, 2019; Jake-Schoffman and McVay, 2020; Sucala, et al., 2020; Nicholas, et al., 2021). All participants discussed the importance of formative testing. Several formative testing objects and software tools were identified as typically being utilised by interdisciplinary collaborating teams when carrying out formative testing activities, and these objects generally function as boundary objects (described in presented in Chapters 5 and 7). Table 9.8 provides a summary of the formative testing objects and software tools; quoted descriptions of each object (if provided by participants); participant codes (PCs) for those who explicitly mentioned each object; and mHealth physical activity intervention app literature that supports the identified objects (if available) or the URL links to design software tools.

*Table 9. 8: Formative Testing Objects and Software Tools: Interview Study Findings [Source: Researcher's own construction]*

| **Formative Testing Object/ Software Tool** | **Description of Design Object/Software Tool** *(if provided by participants)* | **PC Evidence** | **Literature Support or Software URL** |
|---|---|---|---|
| ***Formative Testing Objects*** | | | |
| **Usability/UX Tests** | • *"We did usability tests…"* (PC9)<br>• *"What we're also doing is usability tests…"* (PC1)<br>• *"We did usability testing…"* (PC14)<br>• *"…the usability tests we did…"* (PC26) | PC1, PC5, PC9, PC14, PC18, PC21, PC26, PC31 | Alturki and Gay (2017); Lai, et al. (2019); Lee, et al. (2020); Sucala, et al. (2020). |
| **Test Plans and Study Documents** | • *"…developed test plans, so designing things and setting up how it will be tested…"* (PC16)<br>• *"We created test plans for users, and then distributed those to the users…"* (PC8) | PC8, PC16 | Van Amstel, et al. (2017). |
| **User Interface Review** | • *"As designers, we do something called a UI review. So we make sure that the app screens are in good shape and that nothing is breaking depending on the different devices because they have difference screen sizes."* (PC3) | PC1, PC3 | Vieira, da Silveira and Martins (2019). |
| **System Usability Scale (SUS)** | • *"Yeah, so we used the System Usability Scale, SUS, yeah."* (PC5)<br>• *"…we've used the SUS before as well."* (PC31)<br>• *"We would get user feedback on the based on the System Usability Scale…"* (PC14) | PC5, PC14, PC18, PC21, PC31 | Liang, et al. (2018); Aguilera, et al. (2020); Kim, et al. (2020). |

| | | | |
|---|---|---|---|
| **Mobile App Rating Scale (MARS)** | • *"It's a scale that you can use to assess the satisfaction with mobile apps… the Mobile Application Rating Scale (MARS)."* (PC28)<br>• *"We used the mobile app scoring system or something called the MARS criteria…"* (PC11) | PC11, PC28 | Schoeppe, et al. (2017); McKay, et al. (2019); Bearne, et al. (2020); Roberts, et al. (2021). |
| **mHealth Usability Questionnaire** | • *"It's another scale you can use to assess the satisfaction with mobile apps, let me think… Oh! The mHealth Usability Questionnaire (MAUQ)."* (PC28) | PC28 | Zhou, et al. (2019); Alessa, et al. (2021). |
| **mERA Checklist** | • *"So recently I've been looking into using, I think it's called the mERA Checklist… wait a second while I look it up… Yes, the mHealth Evidence Reporting and Assessment, it's got a checklist."* (PC28) | PC28 | Hardeman, et al. (2019); Laranjo, et al. (2020). |
| **A/B Tests** | • *"We do A/B tests. We might do it by recruiting users or online."* (PC3)<br>• *"We do A/B tests or A/B/C tests with users…"* (PC1)<br>• *"We did A/B testing…"* (PC16)<br>• *"There was some A/B testing…"* (PC27) | PC1, PC3, PC16, PC27 | Fadhil and Wang (2019). |
| **Alpha App** | • *"We did alpha testing… alpha app, internally with the team."* (PC14) | PC14 | Wilson, et al. (2018); Davies and Mueller (2020). |
| **Beta App** | • *"We'd go through the design and testing process. We'd do beta testing with the beta app prototype, but we'd do it with users, only the alpha is internally with the team."* (PC14) | PC9, PC10, PC14, PC26, PC27, PC28, PC29 | Wilson, et al. (2018); Davies and Mueller (2020); Sucala, et al. (2020). |
| **Physical Activity Scales** | • *"We used the IPAQ questionnaire, it's like the International Physical Activity Questionnaire. We used the long version."* (PC25)<br>• *"Then we also had the LASA, the Longitudinal Aging Study Amsterdam, because the app was graded there."* (PC25) | PC25 | Saran, Owoc and Bojar (2018); Poppe, et al. (2019). |
| **Recording Devices** | • *"We've done formative testing using video recordings…"* (PC26)<br>• *"We sometimes use basic voice recording equipment…"* (PC15)<br>• *"Obviously we had the video and audio recording devices."* (PC21)<br>• *"We get the users to play with the app while we video tape record them and ask them questions about the app, or think aloud sessions."* (PC9) | PC9, PC15, PC21, PC25, PC26, PC28 | Alturki and Gay (2017); Lai, et al. (2019); Lee, et al. (2020). |
| ***App Design Software Tools*** | | | |
| **TestFlight** | • *"We did beta testing in TestFlight. You can take screenshots of a bug/error and send it to the developer through TestFlight with comments."* (PC28)<br>• *"I know we used this thing called TestFlight…"* (PC14)<br>• *"We used this app to do tests on our apps, TestFlight, I think."* (PC25) | PC14, PC23, PC25, PC28 | https://testflight.apple.com/ |
| **Calendly** | • *"We are also using Calendly, a tool to set up timeframes where people [test participants] can organise their time slot for joining a test."* (PC1) | PC1 | https://calendly.com/ |
| **UserTesting** | • *"If we're doing a usability test we use usertesting.com, and we can share the screen and publish the app prototype there."* (PC3) | PC3 | https://www.usertesting.com/ |
| **Jira** | • *"We're using Jira as a tool for keeping track of our user stories and bugs and technical stories and tasks. I think we also use Jira wiki."* (PC29)<br>• *"We also used Jira with the research team because they could lead the testing…"* (PC12) | PC3, PC12, PC29 | https://www.atlassian.com/software/jira |
| **Zendesk** | • *"Zendesk is a platform our for customer happiness team to get incoming support tickets, and basically to answer them, which also integrates with Jira. So with our development tracking system."* (PC29)<br>• *"We use Zendesk, follow up tickets from users, like is the user has any issues with the app, or they miss the data, or if everything is deleted, and then we can record this and the support team can help."* (PC3) | PC3, PC29 | https://www.zendesk.com/ |
| **UserZoom** | • *"For testing, so we are using or we have been using Validately, which has been acquired by UserZoom now. So really to be in contact with our users and being able to have the remote conversation and tests, moderated or unmoderated, for example."* (PC1) *[UserZoom acquired Validately]* | PC1 | https://www.userzoom.com/ |

| | | | |
|---|---|---|---|
| **Google Meet** | • *"Then we also use Google Meet or have been using Google Meet a lot for conversations with our users."* (PC1) | PC1 | https://meet.google.com/ |
| **Panel Management Tool** | • *"We are starting with a new tool for panel management, but it's not implemented yet. So, panel management, for specific users, if they want to be contacted for our [user testing] studies. They agree or consent to be contacted for studies, rather than depending on external agencies."* (PC1) | PC1 | - |
| **Qualtrics** | • *"We've used Qualtrics to do surveys. It's just a commercial version of Survey Monkey."* (PC10) | PC10 | https://www.qualtrics.com/uk/ |
| **REDCap** | • *"A piece of software called REDCap. It's a data management tool that has some survey features that can administer online surveys."* (PC22)<br>• *"For studies we use REDCap for data collection."* (PC2)<br>• *"We use REDCap a lot."* (PC26)<br>• *"REDCap to administer the surveys and get the data back."* (PC10) | PC2, PC10, PC22, PC26 | https://www.project-redcap.org/ |
| **Survey Monkey** | • *"For collecting testing data we've used Survey Monkey."* (PC15)<br>• *"Survey Monkey is one…"* (PC29)<br>• *"Sometimes we'll use Survey Monkey just to show users the app prototype and get their feedback on it."* (PC2) | PC2, PC15, PC17, PC22, PC29 | https://www.surveymonkey.com/ |
| **Google Survey/ Forms** | • *"We haven't used Google Survey specifically…"* (PC17)<br>• *"There's Google Survey or Google Forms, but we don't use them. They're not secure, so we use other secure survey tools."* (PC26) | PC17, PC26 | https://www.google.com/forms/about/ |
| **LimeSurvey** | • *"Sometimes we use LimeSurvey."* (PC26) | PC26 | https://www.limesurvey.org/ |
| **SurveyU** | • *"We migrated from Survey Monkey to SurveyU. It's the same thing, just a different provider. Now we're looking for a new one."* (PC3)<br>• *[Tool discontinued as of 31 December 2020]* | PC3 | https://www.surveyu.com/ |
| **Issue Tracking/ Ticketing System** | • *"…and issue tracking, bug bug (sic) tracking, sort of things."* (PC13)<br>• *"We had a ticketing system so that external participants, you know end users, could tell us what's wrong with it [the app]."* (PC12) | PC12, PC13, PC16 | Moran (2015). |
| **Eye Tracking Software** | • *"Eye tracking. We've done eye tracking, where you get heat maps of where users are looking at the app screen. We use it more for testing, like how people pay attention to things on the screen."* (PC9) | PC9 | Short, et al. (2018). |

### *Connecting Devices and Branding*

Many of the participants discussed linking and connecting their mHealth physical activity behaviour change intervention apps with other tracking devices, such as smart watches, heart rate monitors, accelerometers and some well-known internationally branded tracking devices. One of the advantages of connecting with other devices is to ensure the safety and privacy of user data, and to ensure the collection of good quality and accurate tracking data (Gao and Lee, 2019; Boulos and Yang, 2021). Another advantage is related to branding and marketing the physical activity app, by associating it with a credible company or brand (Blandford, et al., 2019b; Angosto, et al., 2020). PC14 reported that *"We've had [physical activity] apps that interact with Fitbits and with Garmin, and Apple Health, Google Fits… so like we use the API so that the users that wear those [smart] devices, we can get their [physical activity] data"*. Overall, participants mentioned the following devices, apps and companies: Fitbit watch, scale and app (PC5, PC9, PC14, PC19, PC21, PC25, PC26, PC27, PC28); Garmin (PC14, PC28);

Microsoft Band, JawBone and Florence (PC21); Google Fit (PC14, PC28); Apple smartwatch (PC28); Apple Health app (PC14); Samsung Health app (PC28); Polar watch and heart rate monitor (PC24, PC28); Mi Band and Shimmer devices (PC28).

In terms of ensuring the collection of good quality and accurate physical activity tracking data, PC28 shared, *"We are measuring [physical activity] behaviour, and so we must use research grade devices to collect data on physical activity patterns and stuff. So those include activPAL devices, which are the gold standard measurement device for sedentary behaviour and for measuring posture. ActiGraph is another accelerometer that measures physical activity. They're a trusted provider of medical-grade biometric monitoring devices"*. Literature confirms the importance of collecting accurate and reliable tracking data, particularly when testing and evaluating mHealth intervention apps intended for promoting physical activity behaviour change (Gao and Lee, 2019; Boulos and Yang, 2021; Nicholas, et al., 2021).

While there are several advantages of connecting mHealth physical activity apps with tracking devices, a few participants discussed the associated challenges and obstacles. PC21 explained, *"We had a lot of issues with getting the fitness tracker to talk to the app platform, like to try and make them work together, there was (sic) a lot of issues trying to find a fitness tracker that would work well with the back end of the app. There can be limitations with what kind of data you can extract and use"*. Similarly, PC7 stated, *"Being able to extract the data you want. We took for granted that we would be able to get access data from what they click on, and how many times they do that and engage with the app, and we took that for granted. And it's quite difficult, in my experience. You need to be quite explicit with the developers in terms of what you actually want to be able to take out of the app per user. That's another thing to consider, like what engagement data do you want?"*.

***Quality Assurance***

Lastly, regarding the iterative design, development and formative testing process, three participants discussed the importance of quality assurance. PC3 explained that, *"in parallel"* to the A/B tests and UI reviews, *"the QA [quality assurance] team checks the app from a technical perspective. So they check if everything is working fine, and that everything is connecting to the services that it needs to be connected to, if the data is being saved properly, and things like that"*. While discussing the formative testing process, PC26 mentioned *"Testing the app with end users and stakeholders, trying to fix up our bugs, and then quality*

*assessment and get feedback. That's a quality improvement cycle"*. PC1 also shared, *"I know that the quality assurance team is getting more into how they can get into the different mindsets of users and really doing analysis and testing from a persona perspective"*.

#### 9.3.5.4 Intervention Content and App Design Feature Objects

As discussed under the *"Design"* objects in the previous subsection, designing mHealth physical activity behaviour change intervention apps quintessentially involves two components, namely (1) the intervention content design, and (2) the app design features. Participants discussed objects and artefacts relating to both perspectives and their responses can be categorised into four subthemes: (1) *theories*; (2) *behaviour change techniques (BCTs)*; (3) *persuasive system design (PSD) principles*; and (4) *gamification*. All four of these subtheme empirical findings were introduced and described in Chapters 3 and 4, and critically analysed in Chapter 6, further evidencing this research project's rigour, credibility and contextual relevance. As illustrated in Figure 9.7, intervention content and app design feature objects (the right-hand side light blue square) provide input into ideation and conceptualisation (step 4 of the interdisciplinary process, Table 9.4) and iterative design, development and formative testing (step 5 of the interdisciplinary process, Table 9.4). Furthermore, depending on the goals and objectives of a given mHealth physical activity behaviour change intervention app project, intervention content and app design feature objects may be considered during later stages (such as steps 6, 7, 8, 9 and 11 of the interdisciplinary process, Table 9.4).

***Theories***

Participants, primarily from health and psychology backgrounds (Table 9.2), discussed the importance of incorporating evidence-based theory into the intervention content design of mHealth physical activity behaviour change intervention apps. Participants most commonly identified the following theories: social determination theory (SDT) (PC9, PC18, PC20, PC21, PC22, PC24, PC27, PC28, PC31); social cognitive theory (SCT) (PC2, PC9, PC10, PC14, PC17, PC22, PC28); theory of planned behaviour (TPB) (PC9, PC10, PC14); cognitive behavioural therapy (CBT) (PC10, PC17, PC20); acceptance and commitment theory (ACT) (PC20, PC24, PC27); and habit formation theory (PC7, PC20, PC31). Mentions were also made of goal setting theory (PC14, PC28, PC29); self-regulation theory (PC23, PC27); motivational interviewing (PC14, PC17, PC28); relapse prevention theory (PC17, PC27); emotional regulation theory (PC27); and social influence theory (PC31). With regard to theoretical models, participants referenced the transtheoretical (stages of change) model (TTM) (PC9); the

elaboration likelihood model (ELM) (PC7); the health action process approach (HAPA) (PC23, PC25, PC28); and the socioecological model (SEM) (PC15, PC21, PC28). Most of these theories and models identified by participants were discussed in Chapter 3 (Section 3.5.1) and have been frequently referenced in literature for informing the design of mHealth physical activity behaviour change intervention apps at the dual intra-interpersonal socioecological level (Fanning, 2016; Wang, et al., 2017; Fadhil and Wang, 2019; Wang, 2019; Haque, 2020).

While theories and theoretical models can be valuable for informing the design of mHealth physical activity apps, several participants highlighted that rather than using full theories or models, they often focus on targeting specific theoretical constructs to change individuals' physical activity behaviour. The most frequently identified theoretical constructs were self-efficacy (PC17, PC19, PC23, PC25, PC31), motivation (PC19), and social support (PC1, PC19, PC22, PC31). PC10 explained, *"I don't think we're bound by any one theory or framework when we're designing new physical activity apps"*. PC19 shared *"I tend to draw on constructs that tap into a range of different theories, so like self-efficacy, motivation and social support, those constructs are part of a range of different theories"*. This eclectic use of theoretical constructs depends on the goals and objectives of a mHealth physical activity behaviour change intervention app project, and is detectable in literature on mHealth physical activity apps (Payne, et al., 2015; Middelweerd, et al., 2018; Milne-Ives, et al., 2020; Petersen, et al., 2020).

In line with the eclectic use of theoretical constructs, several participants described using the behaviour change wheel (BCW) (PC5, PC7, PC9, PC10, PC14, PC20, PC21, PC28, PC30, PC31), the COM-B (competency, opportunity, motivation, behaviour) Model (PC7, PC9, PC20, PC21, PC28, PC30, PC31), and the theoretical domains framework (TDF) (PC28). These theoretical models and frameworks essentially combine key theoretical constructs from a range of health behavioural and psychological theory, and have reportedly been used in the design of various mHealth physical activity apps (Walsh, et al., 2019; Aguilera, et al., 2020; Truelove, et al., 2020). PC10 explained, *"It tends to cut across various different theories, so when you start using the behaviour change wheel and the behaviour change taxonomy to figure out what should go into the intervention, then you're not just using one theory"*.

In addition to the above-identified dual intra-interpersonal theories, less frequently mentioned theories included fun theory (PC14), communication theory (PC9), the model of media attendance (PC31), marketing theory (PC26), consumer expectation theory (PC26), sustainability models (PC26), and economic models (PC26). Moreover, some participants

mentioned theories and models that stem from an information systems/technology background. These included UTAUT1 and UTAUT2 (the two unified theory of acceptance and use of technology models); TAM1, TAM2 and TAM3 (the three technology acceptance model versions); the DART model (dynamic acceptance model for the re-evaluation of technologies); and JITAI (just-in-time adaptive intervention) theory (PC18, PC22, PC26, PC28, PC31). One participant (PC5) also mentioned the WHO's digital health framework.

Overall, while acknowledging and reporting on the various theories, models, frameworks and theoretical constructs used in the design of mHealth physical activity intervention apps is important for enriching the growing digital mHealth app knowledge base, some participants expressed a tendency to favour focusing on BCTs rather than theories. PC10 expressed, *"We've used a very broad suite of theories. But personally, I'm a lot more focused on the behaviour change techniques than the theory because all the different theories come back to using the behaviour change techniques. So yeah, the taxonomy, Michie's taxonomy is something I prefer to use for that sort of thing"*. Michie's (2011; 2013) taxonomies and behaviour change techniques have been discussed frequently throughout Chapters 3, 4, 6 and 7.

***Behaviour Change Techniques***

The importance and use of behaviour change techniques (BCTs) for informing the intervention content design of mHealth physical activity behaviour change intervention apps was discussed by 52% of the participants (PC2, PC5, PC7, PC9, PC10, PC14, PC19, PC20, PC21, PC22, PC23, PC25, PC27, PC28, PC30, PC31). None of the three (3) participants practicing specifically in industry/commercial companies had any knowledge of the BCT taxonomies. Both the 40-item CALO-RE and 93-item v1 BCT taxonomies (introduced in Chapter 3, Section 3.5.5) were generally referenced as taxonomies of choice by most of these participants. PC14, similarly to PC10, explained *"We've tended to use Michie's taxonomy because that's just kind of where the [health psychology and health behaviour change] field has gone"*. Some participants expressed a preference for the latest BCTT v1, while others preferred the CALO-RE taxonomy. For example, PC23 expressed a preference for the CALO-RE taxonomy, justifying *"because it's specific to physical activity and healthy eating"*. In addition to these two prominent taxonomies, two participants (PC2, PC26) discussed using their own internally developed taxonomies (developed by either the team, digital health centre, or university).

A few of the participants discussed the importance of aligning theory, BCTs, determinants and correlates and mechanisms of action; a practice suggested in literature (Michie, et al., 2018a; Carey, et al., 2019; Taj, Klein and van Halteren, 2019; Johnston, et al., 2021). PC10 explained *"Yeah, that's the mapping through the process, linking the determinants and correlates with mechanisms of action and behaviour change techniques. All whilst trying to keep the intervention as simple as possible, and that's the tough bit"*. On another note, some participants cautioned not using all of the BCTs from the CALO-RE and v1 taxonomies; a recommendation stipulated in literature (Michie, et al., 2011; 2013; Bohlen, et al., 2020). PC22 expressed *"I've never set out with the explicit aim of smashing all 93 BCTs within the same intervention. The 93 techniques, it gets a bit overwhelming. But we will try and look at the intervention content, and then more generically, the features that we're developing and look for opportunities that we might be able to strengthen those by putting the BCTs into them."*

When asked which specific BCTs are known to be the most effective at changing individuals' physical activity behaviour through digital intervention app technology, participants reported a handful of BCTs from both the CALO-RE and v1 taxonomies. Table 9.9 outlines the BCTs mentioned by participants, along with quoted descriptions of each BCT (if provided), and the participant codes (PCs) evidencing who explicitly mentioned each BCT. The BCTs detailed in Table 9.9 comprise an amalgamation of the BCTs in the 40-item CALO-RE taxonomy presented in Chapter 3 (Section 3.5.3) and a few select BCTs from the 93-item v1 taxonomy. All of the BCTs identified by participants have been reported on in mHealth physical activity behaviour change intervention app literature (Bondaronek, et al., 2018; Boulton, et al., 2019; DeSmet, et al., 2019; Monteiro-Guerra, et al., 2020; Schroé, et al., 2020; Nicholas, et al., 2021).

*Table 9. 9: Behaviour Change Techniques (BCTs) in mHealth Physical Activity Behaviour Change Intervention Apps: Interview Study Findings [Source: Researcher's own construction]*

| BCT | Application to Physical Activity Apps *(if provided participants)* | PC Evidence |
|---|---|---|
| **Information provision (general)** | • *"…provided users with general healthy lifestyle guidelines and provided links to the national physical activity guidelines"* (PC27) | PC27 |
| **Information provision (others' behaviour)** | • *"…would be able to see other peoples' activities they shared, and you could comment or like their activities"* (PC16) | PC16 |
| **Goal setting (behaviour)** | • *"…they could evaluate their goal in comparison to their physical activity and see how it worked out, and then set new goals based on failure or success"* (PC25) | PC1, PC3, PC9, PC10, PC14, PC20, PC21, PC25, PC29, PC31 |
| **Goal setting (outcomes)** | • *"Goal setting was important, like they set goals around FITT goals… so like frequency, intensity, time and type… so they could set the goal for themselves to achieve"* (PC21) | PC1, PC3, PC9, PC10, PC14, PC20, PC21, PC27, PC29, PC31 |
| **Action planning** | • *"…provide action plans for how they can increase their activity and be more active"* (PC23) | PC10, PC23, PC25 |

| | | |
|---|---|---|
| **Identifying barriers/ Problem solving** | • *"Coping planning… they had to come up with plans for when they couldn't complete an activity, like a plan B"* (PC23)<br>• *"…there was a list of coping plans they could use…"* (PC25) | PC23, PC25 |
| **Review of behavioural goals** | • *"… they could review what their activity goals are…"* (PC9) | PC9 |
| **Review of outcome goals** | • *"People got feedback on whether they met their goals…"* (PC14) | PC9, PC14 |
| **Effort or progress contingent rewards** | • *"…they are rewarded for making progress or if they put in effort, give them positive messages like 'well done!' and stuff"* (PC1) | PC1 |
| **Successful behaviour contingent rewards** | • *"Users can sign up for memberships where they gain points and badges. As they reach different tiers of achievement, they get back benefits as vouchers and discounts to use with [company]"* (PC1) | PC1 |
| **Self-monitoring of behaviour** | • *"…allowed people to record their activity progress"* (PC14)<br>• *"Each day they would indicate if they completed their goal for the day, like a self-monitoring technique, and they would score from one to five how they felt about completing their goal"* (PC23) | PC1, PC7, PC10, PC14, PC20, PC23 |
| **Self-monitoring of behavioural outcome** | • *"You can see what your fastest performance is on a 5K run, for example, or your last walking distance…so you can log your activities and be motivated to break your PBs records"* (PC29)<br>• *"…users can track their steps, and the aim is to get to 10 000 steps, and they can monitor their steps daily…"* (PC9) | PC1, PC9, PC10, PC14, PC20, PC29 |
| **Provide feedback on performance** | • *"People got performance feedback in relation to their goals"* (PC14)<br>• *"They could see a graph of each day, mapping their activity and they could see if they reached their goal or not"* (PC23) | PC10, PC14, PC20, PC23 |
| **Provide feedback on behaviour** | • *"…gave people personalised feedback"* (PC14)<br>• *"Feedback is really important… like providing distance or pace of running or walking… or that physical activity feedback that lets you know you're getting a bit fitter"* (PC21) | PC14, PC20 |
| **Instruction on how to perform the behaviour** | • *"…provide instructions for how to perform strength training workouts…"* (PC3) | PC3 |
| **Demonstrating behaviour** | • *"The app demonstrates some of the activities, particularly for strength training"* (PC10)<br>• *"…virtual assistant… educational videos showed how to do activities…"* (PC14) | PC10, PC14 |
| **Social comparison** | • *"…comparison with others' activities and performance"* (PC14)<br>• *"…the leaderboards motivate people to compare their performance against others…"* (PC29)<br>• *"…where you can see what your friends are doing…"* (PC31) | PC14, PC29, PC31 |
| **Social support** | • *"…social connection and that social support, like building rapport and relationships is something that seems to help…"* (PC21)<br>• *"More integrated in social networks. Giving people the ability to invite their friends to join so they don't exercise alone"* (PC31) | PC1, PC10, PC14, PC21, PC31 |
| **Social norms** | • *[No example provided]* | PC14 |
| **Habit formation** | • *"…that repetition again and again… walking 5km daily"* (PC21) | PC21 |
| **Relapse prevention** | • *"..try to prevent the user relapsing back into old habits of being physically inactive…"* (PC10) | PC17 |
| **Associative learning** | • *"…we may try to design algorithms based on reinforcement learning, so to see how they associate certain things with activity and reinforcing the new behaviour…"* (PC31) | PC31 |
| **Prompt practice** | • *"…kind of like prompt cues…for auctioning activity"* (PC21)<br>• *"…they could get a notification on Monday morning so tell them that they had to go swimming, for example"* (PC23) | PC1, PC10, PC21, PC23 |
| **Material incentive** | • *"…making sure that it's motivational, like applying positive reinforcement"* (PC21) | PC21 |
| **Scheduled consequences** | • *"…accountability… accountability knowing that your physical activity data was being sent back to the cardiac centre…"* | PC21 |

***Persuasive Systems Design Principles***

Overall, only a small handful of participants discussed the significance of persuasive systems design (PSD) principles in designing engaging and effective mHealth physical activity intervention apps. Three participants discussed the value of the persuasive systems design model (PSDM) (PC18, PC 20, PC24). The lack of mention of PSD principles by other participants may be due to a lack of knowledge and experience with the persuasive technology field in general (discussed in Chapter 4, Section 4.4.2 and Appendix E). Some participants' lack of awareness of PSD principles may also be due to the multidimensional and evolving nature of the interdisciplinary mHealth behaviour change intervention app arena. For instance, if some participants primarily practice from a health or health psychology background, they are less likely to hold specialist knowledge and experience with PSD principles, and unless introduced to collaborating with such professionals in interdisciplinary teams, they may not be cognisant of the value the persuasive field can contribute to mHealth physical activity behaviour change intervention app design. However, when afforded the opportunity to collaborate with team members possessing PSD knowledge, they often recognise its value and attempt to incorporate it into their mHealth physical activity app designs. For example, PC20, whose background is in digital health and computer/electrical engineering, has been introduced to the PSDM through interdisciplinary collaboration mHealth app projects. PC20 explained, *"The PSD framework/model is actually one of the frameworks that we often use and often kind of evaluate the different app design features based on that. So like, for example, trying to find a good balance between tunnelling and then providing freedom for the users"*. Having knowledge of PSD principles such as tunnelling was lacking with most other participants.

For participants with extensive knowledge and experience with the PSDM and PSD principles (PC18, PC24), they discussed the opportunities of persuasive design and the positive effect results accruing from their translation and application in mHealth physical activity apps. As a caveat though, PC24 did clarify that not all of the 28 PSD principles outlined in the four PSDM tables (an object identified in Table 9.7) should be employed together in one app. Instead, depending on the goals and objectives of a mHealth physical activity intervention app project, PC24 explains *"...it might be enough that you have a handful of maybe six or nine features, rather than 15 or 25"*. Furthermore, PC24 also discussed the value of defining *"a set of core features"* to focus the team members' attention. This provides *"a good common ground to start talking about what core features will be fleshed out into the actual app, and then asking is*

*something missing or is something that came (sic) on to the list perhaps not really needed"* (PC24). Overall, based on the lack of participants' familiarity with the PSDM and PSD principles, it seems that there needs to be more awareness and understanding of the power of PSD principles and the impact these principles can have on creating engaging and effective mHealth physical activity behaviour change intervention apps (Almutari and Orji, 2019; Aldenaini, et al., 2020; Arjoranta, Kari and Salo, 2020; Haque, 2020; Sporrel, et al., 2021).

***Gamification***

Leveraging the persuasive opportunities presented by gamification and incorporating game elements as app design features in mHealth physical activity behaviour change intervention apps was recognised by 65% of the participants (PC1, PC6, PC7, PC9, PC10, PC12, PC14, PC15, PC16, PC18, PC19, PC20, PC21, PC22, PC23, PC27, PC28, PC29, PC30, PC31). PC19 expressed *"It seems that gamification in physical activity apps is really skyrocketing"*. These sentiments were echoed by PC31, *"The whole gamification thing is really appealing, or integrating with social media or making the [physical] activity app more network based, because there's a lot of opportunities for us to explore the powers of these gamification techniques to influence behaviour"*. This positive view of gamification and incorporating game elements into mHealth physical activity apps has been growing in popularity in recent years (Lee, et al., 2018b; Cotton and Patel, 2019; Othman, Ugap and Rahman, 2019; Khamzina, et al., 2020; Lee, et al., 2020; Cerbas, et al., 2021).

While most of the participants shared a positive view of gamification, two participants expressed ambivalence about the persuasive power of game design and its growing prevalence. PC1 discussed the documentary "The Social Dilemma", elaborating *"…it's a critical topic and it's a topic of ethical awareness. So we don't want to push too much into gamification and persuasion because making people too dependent on our products [physical activity apps] isn't what we want. People spend a lot of time anyway on screens. So it's really about how can we make people more active instead of getting them always in front of their phone. We want to do something good"*. This ambivalence expressed by PC1 has been documented (Lu and Ho, 2020), notably with concerns regarding brand dependency, and gaming and app use addictions. PC29 also expressed caution around *"…not using any dark patterns, which are probably used by some apps to make use of how the human brain works, how people behave, and then kinda tricking them into specific actions they probably don't want to carry out in the first place"*.

Concerns around nudge theory and dark patterns, and their use in mobile apps has been reported on in literature (Di Geronimo, et al., 2020; Luguri and Strahilevitz, 2021).

The ethical use of gamification in mHealth physical activity apps, however, provides opportunities for positively promoting and encouraging behaviour change in individuals. PC15 discussed how gamification (rewards and achievement) can positively motivate physical activity behaviour while being informative and interesting to users. *"For physical activity apps, those lovely little scales that show you moving red to green or gives you a little 'Tada!' reward message or trophy when you hit a milestone; that is meaningful. Whereas a message that says 'Oh just did 30 minutes of vigorous activity a day'. Like, what does vigorous mean to these people? Especially if people perhaps have lower levels of health literacy or who are less motivated"* (PC15). This example demonstrates how simple gamification elements can convey information in an interesting and encouraging way that users understand and can make sense of in their daily lives. Another participant (PC7) discussed the value of gamification in creating enjoyable experiences and sustained behaviour change, *"The reason people do things over and over again is quite different to the reason they do things initially. If you integrate gamification in the app, something useful, fun or satisfying, hopefully people will use it more often, or they won't need it because their needs have been met"*.

Overall, participants provided a range of examples in which gamification had been incorporated and applied in designing effective mHealth physical activity apps. Table 9.10 summarises some gamification examples given by participants; identifying the gamification elements, the quoted descriptions of application in mHealth physical activity apps (if provided), and the participant codes (PCs) evidencing who explicitly mentioned each element.

*Table 9. 10: Gamification in mHealth Physical Activity Behaviour Change Intervention Apps: Interview Study Findings [Source: Researcher's own construction]*

| Gamification Element | Application to Physical Activity Apps *(if provided participants)* | PC Evidence |
|---|---|---|
| **Rewards** | • *"…the app had a game where people would run and catch things and win rewards… they could run and catch normal objects, or catch a basketball, tennis racket or bicycle, and in another game they drove a car, and another one they could ride a bicycle. These games would translate to physical activity and then they would win rewards"* (PC9) | PC9, PC10 |
| **Badges** | • *"There was (sic) badges, like gold, silver and bronze, like star badges, so like a bronze star for third"* (PC18) | PC18 |
| **Prizes** | • *"They can receive prizes for winning a virtual race, like if they came first, second or third running against the avatar or competing against other people they're connect with on the app"* (PC29) | PC29 |
| **Points** | • *"…could get points for activities and performing well…"* (PC14) | PC14 |

| | | |
|---|---|---|
| **Leaderboard** | • *"The app had a leaderboard, the leaderboard was something they really loved… they just wanted to be at the top of the board"* (PC16)<br>• *"…leaderboard that others will see in the community online"* (PC29) | PC1, PC3, PC14, PC16, PC18, PC29 |
| **Ranking** | • *"The first rank position artificial face was looking very much like a prince or queen. The second was looking more lower (sic) rank, so maybe not as nice. Then the third rank was not nice looking, like a bit ugly and low rank, not a prince or queen…"* (PC18) | PC18 |
| **Levels** | • *[No example provided]* | PC18 |
| **Statistics** | • *"…sort of stats, like where steps convert to weight loss"* (PC14) | PC14 |
| **Social pressure** | • *"…they could comment on other peoples' kind of activity"* (PC16)<br>• *"…you can share your success on the leaderboard that others will see in the community online…"* (PC29) | PC16, PC29 |
| **Social status** | • *"…people would comment or respond to others' activity…the comments were very engaging, and getting likes, that was engaging"* (PC16)<br>• *"…you can share your virtual races on Instagram live story and gain followers, and also show off the [company] brand"* (PC29) | PC16, PC29 |
| **Fun** | • *"…integrating something fun in the app, something satisfying and enjoyable like fun game to play with friends"* (PC7) | PC7, PC14 |
| **Role player** | • *"…shooter player games that could benefit motivation…"* (PC1)<br>• *"…role playing, and they played the character of a cat"* (PC18) | PC1, PC18 |
| **Storytelling** | • *"…we created like daily drama soap series, and it had 12 episodes, very short episodes, and it was mostly to get the youngsters who were not motivated to exercise to the use app, and to get them interested in the topic and engage with the intervention"* (PC30) | PC30 |
| **Avatar** | • *"…used an animated character to do some demonstrations of activities such as strength training and weight lifting…"* (PC10)<br>• *"…using an AI, artificial intelligent, avatar… I decided on avatars because its ability to provide intuitive communication, and be able to adopt the image of an exercise professional or personal trainer, and be able to talk like them and mimic them…"* (PC6) | PC6, PC9, PC10 |
| **Customisation** | • *"Users can upload their own profile pictures as an avatar"* (PC10) | PC10 |
| **Gifts** | • *"Users can sign up for memberships where they gain points and badges, and as they reach different tiers of achievement, they get back benefits in the form of vouchers and discounts to use with [company]"* (PC1) | PC1, PC14 |
| **Challenges** | • *"…challenges that motivate and ramp up their game to move"* (PC29)<br>• *"We set up individual challenges each month, like for example, a challenge to try and walk the entire length of the Chinese wall over a few months, which is incredibly long right? It's a challenge"* (PC9) | PC9, PC29 |
| **Competition** | • *"…a game show where contestants would compete to win"* (PC12)<br>• *"…virtual races which (sic) we introduced last year because people couldn't go to physical events because of COVID, so you could set virtual races with other people or avatars…"* (PC29) | PC12, PC29 |
| **Unlocking** | • *"…unlockable features… unlock levels and items…"* (PC14) | PC14 |
| **Socialisation/ Interactive Communities** | • *"We're focusing very much on building a social community/network, like community amongst the users so they feel like a member of the group and that's connect with the [company] brand"* (PC1)<br>• *"…social connection and that social support, like building rapport and relationships is something that seems to help…"* (PC21)<br>• *"You can set up your own groups and communities with some family members or friends"* (PC29)<br>• *"…more integrated in social networks, giving people the ability to invite their friends to join so they don't exercise alone, for example"* (PC31) | PC1, PC21, PC29, PC31 |
| **Progress** | • *"The app had this game that showed their progress over Monday, Tuesday, Wednesday, Thursday, Friday. If they did their activity then the cat would jump over the hurdle or obstacle. But if they missed activities then the cat would be wounded or got sick."* (PC18) | PC18, PC31 |

#### 9.3.5.5 Implementation, Evaluation and Study Objects

Participants identified a variety of objects and artefacts relevant to the steps 6, 7, 8, 9 and 10 of the interdisciplinary process (Table 9.4). The objects identified applicable to these steps can be categorised into three subthemes: (1) *implementation objects*, (2) *evaluation objects*, and (3) *study objects*. As illustrated in Figure 9.7 (the purple rectangle), these objects tend to succeed the iterative design, development and formative testing cycle. Notably, in comparison to the diverse range of iterative design, development and formative testing objects identified by participants, fewer implementation, evaluation and study objects were mentioned.

***Implementation Objects***

Implementation plans were mentioned by two participants (PC26, PC27). In addition, when implementing a mHealth physical activity app or rolling out an updated app version, one participant (PC1) discussed the importance of conducting *"design reviews and code reviews to make sure that everything is implemented as it's designed and that it's working properly, that it's working for both app platforms, so Android and iOS"*. Furthermore, two participants (PC21, PC28) mentioned using the RE-AIM (reach, effectiveness, adoption, implementation and maintenance) framework, which can be used for planning and evaluating public health and health behaviour change interventions, and has been utilised a few times in the mHealth physical activity app context (Blackman, et al., 2013; Kelechi, et al., 2020). Moreover, for *"very big implementation projects"*, PC26 discussed *"creating podcasts"* for implementation actors to listen to, to aid the implementation process.

***Evaluation Objects***

For conducting pilot and controlled trials, several participants discussed registering the trials, creating trial plans, recruitment criteria and recruitment flow charts, and using panel management tools and trial management systems to ensure that trials for mHealth physical activity behaviour change intervention apps are run efficiently (PC1, PC13, PC16). For controlled trials specifically, 52% of the participants discussed RCTs (PC2, PC5, PC7, PC9, PC10, PC14, PC15, PC20, PC21, PC22, PC24, PC25, PC27, PC28, PC30, PC31). Notably, several participants discussed the limitations and challenges associated with conducting traditional RCTs. *"Traditional approaches are too slow because by the time you've finished a year to 18 month trial, the technology has changed and advanced"* (PC14) and *"The traditional RCT doesn't allow you to update the intervention if it hasn't been planned before. So it's a*

*challenge. You're running an 18 month intervention with technology that has been frozen before the trial, and that is challenging for the users especially"* (PC20). Generally, the limitations and challenges associated with traditional RCTs boils down to insufficient time, funding and resources (Collins, et al., 2005; Mohr, et al., 2015; Jake-Schoffman, Silfee and Waring, 2017; Blandford, et al., 2018; Arigo, et al., 2019; McKay, Slykerman and Dunn, 2019).

In light of the limitations and challenges associated with traditional RCTs, several participants detailed using non-randomised controlled trials and other adaptive trial designs to evaluate the efficacy and effectiveness of mHealth physical activity behaviour change intervention apps. PC15 stated that they *"do a lot of convenience sampling"*, and PC20 mentioned *"adaptive setups and adaptive intervention trial methods"*. PC14, however, discussed the general resistance towards non-traditional trials, *"I feel like people who work in this [mHealth intervention] space know it would be better if the trials were adaptive, because of the drawbacks of RCTs, which are so strict. But the peer review process isn't on board. As soon as you do something that's not a rigorous traditional RCT, you get crucified. It sucks. It's a major issue. They're just a bit too left a field with people who are quite old and conservative. I love the idea of adaptive trial designs, and I totally appreciate that there are more and more methods for it. I think it will come with time"*. While describing these challenges, PC14 and PC20 also recognised and mentioned the opportunities afforded by microrandomised trials.

Microrandomised trials were discussed in more detail by PC28, who explained that instead of conducting traditional RCTs – given their limitations – they prefer using MOST (identified in Chapters 4, 6 and 7), particularly in the context of mHealth intervention apps. PC28 elaborated, *"With this new MOST strategy, you would rather enter into an optimisation phase [than RCTs]. This includes running microrandomised trials to understand what parts or what behaviour change techniques, or what intervention functions are having a positive, negative or no effect, in order to then at the end come out with an optimal intervention. So then we end up taking away the bits that don't work or are not used and we end up with an intervention that is most effective"*. This argument that the MOST strategy, microrandomised trails and other adaptive trial designs (such as SMART and N-of-1) should be used more going forward is shared in mHealth intervention literature (Arigo, et al., 2019; Kramer, et al., 2019; Guo, et al., 2020).

Two other participants discussed carrying out ecological trials, pragmatic trials and ecological momentary assessments (PC9, PC31). PC31 shared *"In a couple of studies we've done more what we call pragmatic trials, ecological trials, which wasn't so much whether the users'*

*behaviour changed but whether they sign up for the app or download the app and use it or not. So more about engagement metrics, and in a more natural environment, unlike RCTs, so there's no eligibility criteria. It's a very different approach to a RCT, which is rather more really all about whether their physical activity behaviour changed over time. With the ecological trials, it's more about whether people used the app or not and how they're using the app"*. Ecological trials and ecological momentary assessments have been increasing in use and recognised value in the mHealth intervention app arena, specifically with physical activity behaviour change apps (Kim, et al., 2019; Zapata-Lamana, et al., 2020; Ponnada, et al., 2021).

In addition to pragmatic and ecological trials, two participants discussed using the RE-AIM framework, which can be used for planning and evaluating interventions, as specified earlier. Along with the RE-AIM framework, PC28 mentioned the *"rocket model"*, and elaborated, *"...it's a model proposed by Nutbeam and Bauman, and around evaluation, and it touches on evaluation methods, a process evaluation, and building that into any kind of intervention"*. Mentions were also made of process evaluations (PC10, PC21, PC28), which help to *"look at what happens when we actually try and implement the intervention app"* (PC28).

***Study Objects***

When conducting studies during the evaluation and follow-up stages, several participants discussed using software and tools. PC15 briefly mentioned creating data management plans and using their university's data management system for conducting studies. Four (4) participants mentioned using REDCap (identified in Table 9.8). According to PC2, REDCap is used *"for data collection"*, and according to PC10, is used *"to administer the surveys and get the data back"* from participants. Similarly, PC22 explained that REDCap is *"a piece of software… it's a data management tool that has some survey features that can administer online surveys"*, and PC26 said that they *"use REDCap a lot"*. Furthermore, for quantitative and statistical data analysis participants mentioned using SPSS, Stata and R (PC5, PC19, PC26), and for qualitative data analysis participants identified NVivo (PC25, PC26, PC28). Another participant (PC4) also referenced using EndNote as a reference management system.

#### 9.3.5.6 Post-Release Market Surveillance Objects

Participants identified a few objects pertaining to step 14, *"post-release market maintenance and continuous improvements"*, of the process (Table 9.4). The objects concerned data tracking and app analytics, and monitoring the apps for bugs and issues subsequent to its release on the

commercial app market (on the Google Play and Apple App Stores). As illustrated in Figure 9.7 (the right-hand side pink rectangle) and outlined in Table 9.4, these objects tend to succeed the evaluation and implementation, rollout and release stages of the process.

Several participants with commercially released mHealth physical activity apps reported systems for issue tracking, reporting and customer feedback. Jira and other internally developed ticketing and issue/bug tracking systems were mentioned for tracking bugs and monitoring issues (PC2, PC12, PC13, PC29). When asked about tracking, PC3 explained, *"We have several different types of tracking in place for the app. We have tracking called feature usage, where we see how users are interacting with the app features, where they are tapping, going back and forth with the screens. We also track interaction, when users are opening the app, the app sessions, how many times they spending on each app session. We track all of their physical activities and what they're doing, like running distance, the pace and everything"*.

Firebase, Adjust and Databricks were also discussed for tracking and analytics. *"Firebase measures screen tracking, or how many people are clicking on or navigating through a certain set of screens. It also supports remote configuration, like a feature flag [for] shipping an update, but where we want to hide a specific set of the app until we have a big bang launch"* (PC29). *"Adjust measures the performance of paid user acquisition campaigns; how many people are installing our app, but from which source? A Facebook ad? Is it organic? Is it from Apple search ads?"* (PC29). With regard to app analytics, participants discussed the *"built in analytic possibilities"* with Google Play Store and App Store Connect where *"you can analyse plenty of your performance metrics"* (PC29).

#### 9.3.5.7 Supporting Methods

Supporting methods, as illustrated in Figure 9.7 (the yellow elongated rectangle), provides a cross-thematic foundation for guiding interdisciplinary teams during the mHealth physical activity behaviour change intervention app project process. The supporting methods identified by participants can be categorised into three sub-themes: (1) *project process supporting methods*, (2) *interdisciplinary team supporting methods*, and (3) *activity supporting methods*.

***Project Process Supporting Methods***

Project process supporting methods have largely been described under Section 9.3.4 (the "Main Theme 4: Process"), and will be briefly reiterated here to elucidate the various supporting methods identified by participants. The most frequently discussed project process supporting

methods were *co-design* and *participatory design* methods, recognised by 58% of the participants; processes that have been employed for guiding the design of mHealth physical activity apps (DeSmet, et al., 2016; Verbiest, et al., 2018; Walsh, et al., 2019; Brown, et al., 2020; Martin, et al., 2020; Simmich, et al., 2021). The second most frequently mentioned project process supporting method was Dam and Siang's (2020) iterative five-step *design thinking* process, used by five (5) participants (PC1, PC3, PC18, PC26, PC31).

Other project process supporting methods mentioned by participants included namely: *the MRC guidelines for developing and evaluating complex health interventions* (PC27, PC28); *the intervention mapping (IM) approach* (PC10, PC21, PC28, PC30, PC31); *the development and evaluation process for mHealth interventions* (PC2); and *the person-based approach* (PC25). All four of these processes were critically reviewed and analysed in Chapters 4 and 6, demonstrating the rigour, credibility and contextual relevance of this research project. Additional supporting methods included the MOST approach (PC14, PC28), the user-centred design process (PC18, PC28), the systems development lifecycle (PC13), the contextual design inquiry approach (PC30), and other agile, waterfall, scrum and lean approaches (PC26). Unlike the afore-mentioned approaches (analysed in Chapters 4 and 6), these latter processes (with the exception of MOST) are not specific to the mHealth behaviour change intervention app context; they stem from and are often used in the information systems discipline in general.

***Interdisciplinary Collaborating Team Supporting Methods***

Participants identified a small handful of methods generally used by interdisciplinary teams to facilitate knowledge sharing, communication, collaboration and idea generation. The most frequently identified supporting methods were teams meetings and workshops, the significance of which was discussed by all participants. Team meetings can be held in-person or more recently since the COVID-19 pandemic, participants described team meetings as taking place virtually via videoconferencing technology. PC11 said, *"With COVID, everything's become virtual, so like anything and everything the team does has to be via Zoom or MS Teams"*. Team workshops were also described as useful at certain stages of the process, primarily the project and team formation, ideation and conceptualisation, problem understanding, iterative design, development and formative testing, and modification and updating stages of the process. Literature on mHealth intervention apps has reported the value in conducting team workshops (Bradway, et al., 2020; Martin, et al., 2020).

Other interdisciplinary team supporting methods mentioned included crazy 8's (PC1, PC3), which is a design sprint method. PC3 explained *"We use crazy 8's. You have 60 seconds and eight minutes to draw eight screens. It's just throwing out ideas. Some people use iPads or tablets, or pen and paper and take a photo"*. Another team brainstorming method mentioned a few times was whiteboard meetings and sessions (PC1, PC15, PC20, PC27, PC28, PC29, PC31). Lightning talks and SWOT analyses where other methods used by teams to analyse *"the strengths and weaknesses of our own app products and competitors"* (PC1).

***Activity Supporting Methods***

Activity supporting methods refer to methods and processes that are often employed by interdisciplinary teams to carry out specific activities or tasks at various stages the project process, particularly during the iterative design, development and formative testing, pilot testing, controlled trial, follow-up and post-RCT steps.

During the iterative design, development and formative testing stage, several participants mentioned using A/B testing or A/B/C testing (PC1, PC3, PC5, PC14, PC16, PC27, PC29, PC31). PC1 described *"launching the app with an A/B test or A/B/C test, and then waiting a few weeks to see what's working best, what's the best option"*, and PC16 mentioned *"presenting users with two app screens and then users provide feedback on which one was better"*. PC29 mentioned using Firebase for conducting A/B tests because *"...you can control who is seeing which version of an A/B test"*.

Additional iterative design, development and formative testing methods frequently identified were alpha testing (PC1, PC3, PC14, PC20, PC29) and beta testing (PC1, PC3, PC9, PC10, PC14, PC26, PC27, PC28, PC29). Alpha testing was referred to as being used internally within the team or commercial app company (with an alpha app version), while beta testing was described as being used with end user representative groups (with a beta app version). Moreover, other iterative design, development and formative testing supporting methods identified by participants included concept testing (PC3), user testing (PC9, PC11, PC12, PC22), usability testing (PC1, PC3, PC5, PC6, PC7, PC11, PC14, PC18, PC21, PC26, PC28, PC31), and feasibility and acceptability testing (PC7, PC11, PC18, PC20).

Mentions were also made of the think aloud technique (PC1, PC3, PC7, PC9, PC10, PC14, PC20, PC25, PC29), task analysis (PC1, PC3, PC9, PC14, PC16, PC29), and user scenarios (PC11, PC20). For the think aloud technique, PC7 explained, *"We do a lot of think alouds with*

*users where we go, 'Okay, what did you think of this? As they go through the app, we ask them to explain the decisions they're making and why they click on certain things. It provides more specific feedback in terms of what to change in the app"*. Conducting user scenarios was similar. PC11 shared asking users *"What do you like? What are your views? Is there something you'd like different?"*, and PC22 described *"…giving users some design mock-ups and asking them to go through different scenarios so we see how the user would use the app, and see how different designs impact on what we're trying to deliver"*. All of the design, development and formative testing methods mentioned above provide ways of gathering user feedback, inform the refinement and improvement of apps, and are used in the design and development of mHealth physical activity apps (Al Ayubi, et al., 2014; Short, et al., 2018; Fischer, et al., 2019).

Some other activity supporting methods that were frequently identified by all 31 participants included focus groups, interviews, questionnaires and surveys. These methods can be employed during various stages of the process (such as formative research, formative testing, follow-ups and post-RCT steps), used for different purposes, and conducted with either stakeholders or end users. PC10 described using *"focus groups and semi-structured interviews for more detailed feedback"*. PC21 referenced *"doing interview and focus groups with multiple stakeholders, so not just end users, but also people who will be involved with implementing the app intervention as well"*. For questionnaires, PC18 described *"using a seven-point Likert scale, with answers ranging from much worse to much better for whether the app helped them increase their physical activity"* over time.

Other referenced methods included microrandomised trials, pragmatic trials, ecological trials, ecological momentary assessments, and field tests (PC3, PC9, PC10, PC14, PC20, PC28, PC31). Field testing, for instance, was described by PC10 as *"trying to evaluate the apps in more real life settings, using a more hands off approach… [which] gives you insight as to how the app is used outside of a research study"*. For controlled trials, activity supporting methods mentioned were generally RCTs (discussed in Subsections 9.3.4.1 and 9.3.5.5). To assess, measure and evaluate physical activity behaviour change as a result of mHealth physical activity app use, participants mentioned step count, distance and pace (PC3, PC9, PC, PC15). PC10 explained, *"At minimum it's the volume of [physical] activity, so duration or if the activity is moderate or vigorous. More recently looking at strength training and muscular strength training, to assess and measure that. Then there's MVPA which can be either self-report or an accelerometer is used"*. These measures were discussed in Chapter 3 (Subsection

3.4.2.1) and are often reported in mHealth physical activity behaviour change intervention app literature (Recio-Rodriguez, et al., 2016; 2018; Monteiro-Guerra, et al., 2020).

Overall, many participants discussed the transition from using activity supporting methods for in-person studies to virtual studies, and elaborated on some of the pros and cons of this virtual transition. PC11 shared, *"Last year we did a complete full virtual trial, everything was virtual, from the recruitment, data collection, you know, all the trainings, focus groups, interviews, everything was virtual. So yeah, the world's changing, it's changing very quickly"*. This transition to virtual studies since the global COVID-19 pandemic outbreak has been reported in literature (Porter and Hook, 2020; Vargo, et al., 2020; Dodds and Hess, 2021).

#### 9.3.5.8 Standards and Guidelines

Standards and guidelines, as illustrated in Figure 9.7 (the right-hand side green rectangle), are used to inform various activities in the iterative design, development and formative testing, pilot testing, implementation, evaluation and post-release market stages of the interdisciplinary process. The most commonly recognised standards and guidelines for designing and developing mHealth physical activity behaviour change intervention apps were the material design guidelines and app quality guidelines published by Android and the iOS human interface guidelines published by Apple. PC14 explained *"Like, with our apps, on iPhone, it's more common to have menu stuff at the bottom, whereas on Android it's more common to have menu stuff at the top. And the way you move between tabs, and that sort of thing is a little bit different on their operating systems"*. Notably though, some participants voiced frustration around adhering to these guidelines, specifically *"the restrictions for Apple devices"* (PC8), and expressed that the stringent standards can be *"a hassle, with iOS especially"* (PC20). Also related to design guidelines, but of a far less official nature in comparison to Android and iOS guidelines and standards, one participant (PC11) explained, *"Sometimes when I'm thinking of colours for the app prototype, it's like we have to abide by the branding of the broader project in terms of colour scheme and fonts and themes"*.

Several participants located in European countries identified the European Union's GDPR (general data protection regulation) (PC1, PC3, PC18, PC20, PC24, PC29). PC3 discussed facing and overcoming the challenges of adhering to the GDPR, *"The app uses your GPS [and] this opens up even more privacy issues. Because if I have a public profile, anyone can see my running routes, so they can see exactly where I live. Because, yeah, I'm running a lot. We also need to adjust how we collect and store user data, depending on the region, depending on the*

*country"*. Further elaborating, PC3 said, *"Also something new that is collecting information in order to advertise other things. So yeah, in general, the App Store for iOS, for example, it's tracking everything. So we need to give users the option to allow this or not. Simple things like accessing the camera, the microphone, all this kind of stuff needs to be in place because everything is related to privacy in a way. The GDPR is really there to protect peoples' information"*. The GDPR has been recognised in mHealth physical activity literature (Muchagata and Ferreira, 2018; Guo, et al., 2020).

In terms of guidelines for physical activity and exercise specifically, some participants identified the WHO's physical activity and sedentary behaviour guidelines (PC1, PC9, PC10, PC21, PC27, PC28, PC30, PC31) (discussed in Chapter 3, Subsection 3.4.2.1). Several participants referenced national physical activity guidelines, including countries such as Ireland, Belgium, Australia, Brazil and the United Kingdom (PC2, PC5, PC9, PC10, PC11, PC15, PC21, PC22, PC31). A few participants also mentioned physical activity guidelines for individuals with specific chronic conditions, such as the Australian Heart Foundation's and Cardiac Rehabilitation Association's physical activity and exercise guidelines. Another two participants (PC10, PC22) mentioned using the American College of Sport Medicine's (ACSM) guidelines for strength training and conditioning. In addition, PC22 mentioned using the ACSM's clinical exercise physiology guidelines, and PC21 described using the FITT (frequency, intensity, time, type) guidelines to measure physical activity. Furthermore, one participant (PC20) described using national guidelines related to measuring physical activity and provided an example of BMI (body mass index) guidelines. They (PC20) explained that *"BMI limits may be different in China than they are in Europe"*. Moreover, a few participants discussed using the 10 000 steps strategy, which is not an official physical activity guideline, but instead has gained worldwide popularity through social media, advertising and marketing (Vandelanotte, et al., 2020).

With regard to reporting and publishing mHealth physical activity behaviour change intervention app literature, some participants mentioned using the CONSORT-EHEALTH guidelines (PC10, PC14, PC20, PC25) (reviewed in Chapter 4 (Section 4.4.2) and Chapter 6). In addition, the TIDieR checklist and guide was mentioned by one participant (PC14), which is useful for guiding the reporting of health interventions in general, yet is not specific to the mHealth app platform (Agarwal, et al., 2016). Associated with reporting is the actual planning and conducting of studies, in which case most of the participants discussed the importance of adhering to and following ethical guidelines and standards. In addition, when conducting

qualitative research, one participant (PC25) described using the COREQ (consolidated criteria for reporting qualitative research) checklist.

Other guidelines and documentation identified included: the WHO's *Global Action Plan on Physical Activity* (mentioned in Chapter 3); the WHO's *Global Strategy on Digital Health*; the *MRC guidelines for developing and evaluating complex health interventions* (analysed in Chapter 6); the *Horizon 2020* initiative; and the WHO's *Be He@lthy, Be Mobile* handbook (PC2, PC5, PC21, PC27, PC28). One participant described policies around app disclaimers, particularly concerning physical activity, *"When it's a brand new user to the app, we have a disclaimer saying that the workouts are proven and that there's science behind it, but if you experience any kind of discomfort in your body, stop using it. Avoid any kind of injury, always have a reference from any doctors or personal trainers or stuff like that"*. Another participant provided a valuable finding, mentioning the increasing use of guidelines for diversity and inclusion (PC2). Furthermore, some participants briefly mentioned standards and policies regarding pairing, connecting and syncing apps with other devices such as smart watches (for example with Fitbit, Garmin and Polar); a topic reported in literature (Zhou, et al., 2019).

#### 9.3.5.9 Supporting Materials and Artefacts

Supporting materials and artefacts, as illustrated in Figure 9.7 (the red elongated rectangle), provides a cross-thematic foundation for supporting collaborating team members' activities throughout the interdisciplinary project. The artefacts identified by participants can be categorised into two sub-themes: (1) *supporting materials*, and (2) *supporting artefacts*.

***Supporting Materials***

The most frequently mentioned supporting material was literature. Literature is a cross-thematic material applicable to all steps of the interdisciplinary project process, although participants often referenced conducting literature reviews during the earlier process stages. PC10 described looking at *"existing systematic reviews and evidence, like what are the effective approaches for a particular behaviour? What works for physical activity? And you know that varies slightly between health behaviours, like between sleep, eating and physical activity"*. The same view was shared by PC30, who explained, *"The whole process of developing an app usually starts with a literature review on what is the behaviour? What are the main determinants of the behaviour?"*. The importance of clarifying what demonstrates effectiveness in physical activity specifically, and how it differs in relation to other health

behaviours, was discussed in Chapter 3 (Sections 3.3 and 3.4) (Rhodes, et al., 2017; Wang, 2019). Performing literature reviews constitutes a common practice in academic and research projects on mHealth physical activity apps (Lee, et al., 2018b; Monteiro-Guerra, et al., 2020; Truelove, et al., 2020; Nicholas, et al., 2021).

Other frequently mentioned supporting materials classify as stationery and devices. PC31 explained, *"When we have like focus groups or co-creation sessions, the materials vary from post-it notes to drawing boards, to anything creative… visualising the concept of physical activity, making dolls, drawing pictures, using wax crayons, colours, drawers, pencils, permanent markers, fluorescent markers, paper, cardboard, colour paper, scissors, glue and other things"*. Along with stationery and creative supporting materials, all participants recognised using technology and a variety of devices to help support their activities at different stages of the interdisciplinary process. Participants spoke about using computers, laptops, printers, scanners, projection screens and mobile devices. To conduct formative testing, pilot trials and evaluation studies with end users, participants mentioned using devices such as mobile phones, smartphones, tablets, laptops, accelerometers, heart rate monitors, smart watches, fitness tackers, and wristbands. Some specific devices included activPAL, ActiGraph, Mi Band, Microsoft Band, Shimmer devices and Fitbit watches. Mentions were also made of voice and video recording devices, cameras, pictures and paper printouts (of wireframes and app screens) for end user studies. Some mHealth physical activity app literature has reported using such creative and technological devices during the design, development and evaluation process (Morenga, et al., 2018; Verbiest, et al., 2018; Ni Mhurchu, et al, 2019).

Several participants discussed the use of social media platforms as supporting materials, including LinkedIn, Twitter, Facebook and Instagram (PC6, PC9, PC14, PC16, PC18, PC19, PC26, PC28). Some participants discussed using social media platforms for communicating with other team members (PC14), while others discussed linking their apps with social media platforms, and designing chatbots with Facebook messenger (PC6, PC9). Several participants discussed the value of using social media to recruit real world end users to participate in studies, such as paid advertising on Facebook, Instagram, LinkedIn, Twitter and Google (PC19, PC28).

***Supporting Artefacts***

The main supporting artefact discussed by all of the 31 participants were existing mHealth physical activity apps. When conducting market reviews, competitor analyses and going

through the ideation and conceptualisation process, participants stressed the value in reviewing existing mHealth physical activity consumer apps, both in research and on the public commercial Google and Apple App Stores (PC1, PC2, PC9, PC11, PC14, PC19). PC19 described *"Looking at commercial apps like Strava and Fitbit, and research apps"*. With regard to commercial consumer apps, PC1 voiced, *"Every month there's at least a few new physical activity apps on the market, like for running, training, workouts and stuff. Some even copy our features and visual style, so we do competitor analyses on a regular basis. Sometimes we download the apps and see what is in the paid and free features. How do we compare to that?*". PC2 expressed *"We look at what's out there… what has proven to be effective, and what people are using on the app stores"*. As part of formative research PC14 shared *"…during the early formative research, we might sort of show people the look and feel of other physical activity apps to get a sense of what kind of style we should be aiming for"*.

### 9.3.6 Main Theme 6: Knowledge

Knowledge represents the sixth main thematic finding of the interview study. This sixth theme corresponds to the proposed Interdisciplinary mHealth App Design Framework's fourth theme (namely *"Main Component 4: Knowledge"*) (Chapter 7, Section 7.6). The knowledge theme can be divided into three subthemes: (1) *key knowledge related challenges*, (2) *overcoming knowledge boundaries*, and (3) *knowledge brokering*. Figure 9.8 provides a diagrammatic illustration of the key knowledge theme and subthemes; discussed in the subsections below.

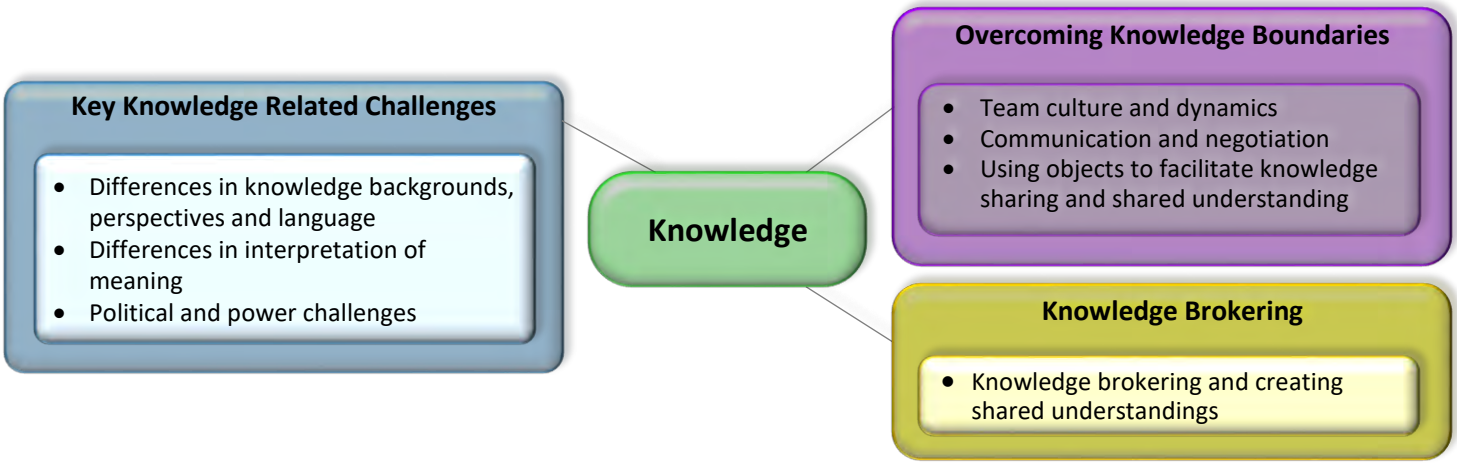



*Figure 9. 8: Knowledge (Main Theme 6): Interview Study Findings [Source: Researcher's own construction]*

A key insightful finding of the knowledge section of the interview, in comparison to the other actor, process and objects interview sections, was participants' explicit acknowledgement and

proclamation for a general lack of solutions to address the complexities and difficulties associated with interdisciplinary team collaboration in the mHealth physical activity behaviour change intervention app space. In other words, when asked about actors, the project process and objects, participants were able to comfortably and competently respond. However, when asked about interdisciplinary team knowledge practices, and how collaborating teams can effectively overcome knowledge boundaries, participants generally expressed hesitation and uncertainty, with several willingly declaring they did not have any substantial solutions. For example, when asked about overcoming knowledge related challenges, PC28 responded, *"I don't know. I don't know because I'm in this situation right at the moment, and I don't know how to solve the problem. I guess you're asking me for solutions, and I'm like 'Please someone tell me the solution!' Because I experience it right now and it's super challenging. I just don't know"*. Two other participants (PC2, PC20) said, *"That's a really good question"*. PC10 replied saying, *"It is very real and challenging"*, PC13 responded, *"That's a very pointed question, because I am coming across this issue now"*, and PC9 replied, *"With a lot of head-butting"*. Notably though, while participants generally expressed not having any ideal or exceptional solutions for addressing the main knowledge boundaries, their responses shared similar themes in the way they usually navigate and resolve knowledge related challenges.

#### 9.3.6.1 Key Knowledge Related Challenges

The key knowledge related challenges facing interdisciplinary collaborating teams on mHealth physical activity intervention app projects can be categorised into three sub-themes (summarised in Figure 9.8): (1) *differences in knowledge backgrounds, perspectives and language*; (2) *differences in interpretation of meaning*; and (3) *political and power challenges*.

***Differences in Knowledge Backgrounds, Perspectives and Language***

Differences in knowledge backgrounds and perspectives – as discussed in Chapter 4 (Sections 4.4.1 and 4.4.3) and Subsection 9.4.5.2 – are generally strongly contrasted between the health and technology fields (Sullivan and Lachman, 2017; Blandford, et al., 2018; Blandford, 2019a). Based on experience in practice, participants reinforced the literary reports of this disparity. PC2 confidently expressed that *"…the biggest kind of disconnect we've seen over the years is between the IT people and the health people"*. PC5 provided an example of this: *"When designing and developing apps, the health people value the intervention contents and the BCTs and stuff, whereas the IT people value innovation and cool aesthetics and features"*.

The differences in perspectives between industry and academia/research were discussed by several participants. PC22 spoke about industry preferencing aesthetics and volume downloads over scientific theory and evidence bases, whereas research stresses a *"solid scientific evidence for scientific evaluation"*. The lack of theory and evidence based commercial apps has been reported in literature (Cowan, et al., 2012; Truelove, et al., 2020). Furthermore, PC22 discussed the different perspectives in carrying out the app design, development and evaluation process, highlighting that the commercial app process is quicker and uses different evaluation and tracking techniques, whereas the research process is slower and emphasises conducting rigorous scientific trials to demonstrate effectiveness. These industry-academia distinctions are supported by mHealth intervention app literature (Ford, et al., 2019; Liu, eta l., 2019).

Adding to this disparity in perspectives between industry and academia/research, PC19 articulated *"Research is more about advancing knowledge, whereas industry and commercial apps are more about making money"*. This view was similarly held by PC27, who shared their experience in working with *"a commercial company and the exploitation side of things"*, in which case the industry partners wanted to publically release the app on the market as soon as it was developed, whereas the researchers wanted to conduct a rigorous RCT to evaluate the app's effectiveness. PC27 explained *"It shows the different interests and goals between commercial companies and research institutions"*. Literature has reported on these key differences in perspectives, interests and goals, with industry/commercial companies known to value profits, and academia/research known to value public health promotion (Ford, et al., 2019; Liu, eta l., 2019; Ford, et al., 2021).

In addition to the identified differences in perspectives between health and technology, and industry and academia, PC18 and PC28 also discussed the differences in perspectives betwixt people in technology, health and business. *"Business and business models aim to prove something conceptually"*, whereas technological models want to *"prove something by seeing the inputs and outputs… the physical things, the coding or software"*, explained PC18. Another challenge attributable to differences in perspectives and interests between people in health and business was discussed by PC28, *"The business people just want numbers and scale… to see their app has been downloaded by 5 million people. They don't care if people downloaded it and opened it once. They only care about selling it and making money. Whereas the health people value app intervention engagement. So even if only 50 people downloaded the app but it really helped them change their physical activity behaviour, then that's more important"*.

This again highlights differences in interests, values and goals between heterogeneous collaborating team members.

Differences in knowledge backgrounds was also described by some participants as having an effect on how BCTs are translated and operationalised as app design features. PC25 described how this challenge is exacerbated since *"there's no one way of mapping certain BCTs with app design features"*; a challenge discussed in Chapter 4 (Section 4.4.2) and supported by literature (Kaptein, et al., 2015; Sporrel, et al., 2021). PC10 also discussed this challenge and, as a health and physical activity expert, expressed the difficulties faced when working with developers to operationalise theoretical constructs and BCTs as interactive and engaging app design features, and how intervention content can be designed and delivered effectively in ways that create for positive user experiences and effect changes in individuals' physical activity behaviour.

From an alternative view, while differences in disciplinary backgrounds and perspectives present challenges, two participants pointed out how these differences can create opportunities and advance knowledge in the interdisciplinary mHealth physical activity intervention app field. PC19 voiced, *"I think it's a good thing. Like it brings in different perspectives, and makes the product [app] much richer and adds depth of knowledge. It's beneficial and important"*. With similar sentiments, PC1 shared, *"We give our best to really acknowledge these differences and appreciate them to some extent because that's also what makes our [physical activity app] products better in the end… these differences can be opportunities to learn from each other"*. Leveraging these differences in perspectives is also argued for in literature on mHealth behaviour change intervention apps (Peiris, Miranda and Mohr, 2018; Hermsen, et al., 2020).

***Differences in Interpretation of Meaning***

Semantic differences in interpretation of meaning and the phenomenon of interpretive flexibility, as discussed in Chapter 4 (Section 4.4.2 and Subsection 4.4.3.2) and reported in literature (Star, 2010; Yardley, et al., 2015a; Blandford, et al., 2018; O'Cathain, et al., 2019; Rousseau, et al., 2019; Tharchen, Garud and Henn, 2020), was further confirmed by participants' responses regarding the disparities between health and technology. PC2 spoke about the *"disconnect… between the IT people and the health people"* and how they *"use the same words to mean slightly different things"* and that it *"takes a while of working together to really understand these differences"*. Likewise, PC5 mentioned, *"I learned early on that we have similar names for different things across different areas. Language is an important thing*

*and making sure everyone is on the same page is key"*. To support common meanings and shared understandings in this instance, PC2 discussed the value in using Jira (Tables 9.5 and 9.8) to document different term interpretations between health and technology team members, to *"make sure that we're understanding each other and how we each use words differently"*. Furthermore, PC20 expressed *"It's a real problem the people in technology and people in health interpret the same words differently cause it means completely different things. For instance, 'pilot study'. If we apply that in technology it means something very different than when a clinician or health professional uses 'piloting' to mean an RCT"*.

PC15 discussed differences in the interpretation and meaning of language depending on disciplinary background and stated that *"...often specific language can get in the way"* when communicating within interdisciplinary collaborating teams. As a health professional, PC15 shared an example of their pre-conceived understanding of what they initially thought constitutes an app, *"I learnt that what I thought was an app is apparently not what an app is. We wanted something with artificial intelligence [AI] and the software developers had to sit me down and explain that what I was describing I wanted wasn't actually an app. Instead it was a decision making tree and that they're not the same thing because you can't have AI unless you have some information for it to learn from and what we were wanting didn't have that information"*. PC15 described this experience as *"a really illuminating conversation"*; an experience that though communication and active listening, revealed previously unknown differences in interpretation of meaning and shared semantic understanding.

Uncovering unknown semantic differences was also discussed by PC24, who highlighted knowledge sharing issues as arising as a result of assumptions being taken for granted. PC24 explained, *"Often times there is a seemingly shared understanding about things and the use of the same terms, but actually they mean very different things to different people. And then only at a later stage in the project do they realise their initial assumptions about what they thought others understood some terms to mean, actually meant something very different. And the problem is, if agreements were made using terms that had different meanings to different people, then conflicts come up because the other party will be like 'No no no, we never agreed to that' meanwhile it's because of this seemingly shared understanding that actually wasn't shared in the first place. And resolving that is challenging"*.

With regard to examples of interpretively flexible terms, participants identified the following: *"pilot study"*, *"piloting"*, *"pilot test"*, *"formative testing"*, *"usability"*, *"summative testing"*,

*"effectiveness"*, and *"implementation"* (PC5, PC20, PC24, PC26). PC24 described these terms as *"…dangerous words because people immediately think they have an idea about what is being said, but actually it means something totally different to software people versus people in psychology, or health or medicine… words that mean different things can be dangerous and cause problems"*. PC26 spoke about how *"effectiveness"* is interpreted differently between people in economics, business, psychology, health and technology, and highlighted the importance of maintaining consistency and *"making sure we apply those same definitions every single time we use those terms"*. PC5 discussed *"the term implementation, to some people, means after the trial and after you've gone through the clinical effectiveness evaluation, then you implement the app into practice. Whereas for other people, implementation means the trial itself, the stage of finalising the app's development and then starting the trial, the trial itself is the implementation"*. All of these interpretively flexible terms were discussed and supported by literature in Chapter 4 (Section 4.4.2 and Subsection 4.4.3.2) (Yardley, et al., 2015a; 2015b; 2016; Blandford, et al., 2018; Morrison, et al., 2018; O'Cathain, et al., 2019).

***Political and Power Challenges***

Over-and-above the obstacles faced in terms of language, terminology and interpretations of meaning, PC11 expressed that working with *"purely based IT people"* is often challenging because they are *"not open to the way things work or the way things are developed beyond the boundaries of IT"*. They (PC11) later rephrased this, saying *"I think the challenge is not as much about differences in language, but differences in ways of working and thinking. How things are conceptualised and how do we push the boundaries and create innovative products [apps] beyond the boundaries of IT? The challenges and complexities that's too complex for a glossary to solve"*. These sentiments were shared by PC9, who expressed *"It's not just language, it's about how people look at things, including programmers, people in health informatics, design, communication, health behaviour, and marketing. It's about how different people think and how this influences the way they approach problems and solutions"*. Essentially, PC9 and PC11 are describing facing increasing differences, dependencies, complexities and novelties associated with the pragmatic knowledge boundary (described in Chapters 5 and 7 (Section 7.6.1 and 7.6.2)) (Carlile, 2002; 2004).

At the pragmatic knowledge boundary, team members often have different, and at times clashing, expectations of one another, giving rise to political knowledge challenges (Carlile, 2002; 2004; Morley and Cashell, 2017). PC11 articulated, *"I come from a health background*

*[and] the IT team is only interested in codes. The IT team will say 'Tell me exactly what you want' and I'm like 'I don't know what I want, you must tell me the opportunities with technology and what's possible', not 'But code wise, this doesn't work', so we can create something innovative together rather than expecting me to tell you exactly what to do"*. Later on, PC11 reiterated *"I wish technologists would adapt a little bit of creativity and imagination, as opposed to being limited within the binary 0 1 coding structure. Of course coding is limited, but the thinking and problem solving shouldn't be limited"*. PC9 held the same views, stating, *"A good developer comes up with creative workarounds. They don't say 'This can't be done. That's not possible'. If you can't fix it you're not a real developer. Everything is possible. It's creative thinking"*. PC22 also conveyed developers should not *"just do the donkey work"* but should be *"useful contributors to how the design and development of the app comes together"*.

In comparison to PC11 and PC22, PC10, who is also from a health background, expressed an alternative opinion of expectations. *"It's getting the tech guys to execute it the way that you want"*, and provided an example where the developers were asked to *"design a better way for people to enter sleep times"*, and while they *"came up with a way that from their database end works beautifully… testing showed it was a massive pain in the backside from users' perspectives"* . This resulted in them requesting that the feature be redesigned more simply, and *"they [the developers]had to make the changes and do what we wanted them to do"*.

However, when interviewing participants with systems and technology backgrounds, they expressed similar frustrations as the health professionals, but the converse thereof. They explained that health professionals often have high expectations that are *"impossible"* and *"unrealistic within the constraints of the project"*, or that *"they may have seen some fancy gadget and expect that anything can be done, like it's magic"* (PC12). PC12 shared an experience where they resorted to telling the health team members *"What you want us to do is either going to require giving us another A$100 000 of funding and we can employ more people to do it, give us like six months to do it. That got the message across to them"*.

Managing and negotiating expectations within in interdisciplinary team is important (Nancarrow, et al., 2013; Morley and Cashell, 2017; O'Reilly, et al., 2017). On the one hand, PC9, PC11 and PC22 expressed expectancies for app developers to be more creative and imaginative, whereas on the other hand, PC10 described their expectations of developers to do as requested by the health professionals and to not practice free-reign creativity or innovation beyond what was expected of them. This is an insightful finding since it demonstrates that

developers on mHealth physical activity intervention app projects often receive conflicting messages from their fellow health team members based on different expectations of their role as developers in the interdisciplinary team. This challenge becomes more convoluted because, as shared by PC12, health team members in turn often fail to acknowledge their own unrealistic or impractical expectations of developers. Notably though, this issue is something that can be addressed and resolved within the team through open communication and transparency (O'Reilly, et al., 2017). For instance, PC26 highlighted the importance of *"being open and transparent about what your expectations are of people"*. Based on their experience of managing expectations, PC15 stated, *"I think the most important thing is to be really clear from the onset what your expectations are going to be for one another… and what each person should contribute"*. Furthermore, PC15 described the importance of managing expectations between industry and academia/research, and expressed that *"industry has very high expectations, because they want value for money out of research. But there's a very poor understanding of how expensive and time consuming research can be, so keeping channels of communication open to manage expectations is really important with working with industry"*.

PC15 further explained that *"we all have these lofty goals of what we want the outcome to be, but we don't always understand how peoples' different interests affect achieving these goals"*. In addition, PC25 spoke about clarifying expectations from the start of the project, and aligning those expectations with the *"shared aim"*. These explanations link managing expectations with managing the different interests, goals and aims within teams (Morley and Cashell, 2017), which also operates on a pragmatic and political level in interdisciplinary mHealth physical activity intervention app projects (Carlile, 2002; 2004).

Managing expectations is closely associated and influenced by the extent of mutual respect within the interdisciplinary team (Lakhani, Benzies and Hayden, 2012; Melville-Richards, 2015; Morley and Cashell, 2017). A lack of respect for the various heterogeneous backgrounds and contributions offered by each team member can hinder the potential success of mHealth intervention app projects (Woods, et al., 2019). PC28 shared their challenging experience on a project where they were the sole *"physical activity expert"* on the team, and their views, opinions and suggestions were not respected or trusted by others. PC28 provided an example, describing their preference for adopting a *"formative user-centred design iterative process that involves end users from the start, whereas... the Computer Science people, the programmers think that end users don't know anything and shouldn't be involved from the start"*.

As another example, PC28 had expressed to their team the relevance of integrating components for depression and anxiety into the main app intervention, but their suggestions were not heard or acknowledged by the other team members. However, when a psychiatrist was consulted and made the same suggestion, the team did not hesitate to take on board their recommendation. PC28 articulated, *"It's such a big challenge because it's part of the team dynamics that they only respect you if you're seen as more of a reliable source like an expert, doctor or professor, then they're more respecting and trusting in what you say"*. Addressing this challenge, PC28 elaborated, requires either having one or more *"allies on your side to back you up"* or *"gaining the respect and trust of the PI, and having the PI on your side supporting you, because when the PI says it, the team listens and respects what they say. But without an ally or the support of the PI, then nobody's going to pay attention to what your views are"*.

Political and pragmatic challenges also arise due to access rights and restrictions within interdisciplinary teams. For example, PC17 (a clinical health professional) shared experiences where they have had limited to no access to the app platform and as a result, were not able to insert and adjust the app's intervention content. They (PC17) explained, *"I'd prefer to administer the intervention content on the platform myself. It got very frustrating because I couldn't personally enter text and pictures, so I couldn't see what it would look like. I'd have to wait for the developers to do it to see what it looks like… it inhibits my impulse. I have to ask them to do it for me. It wastes so much time waiting for them to implement changes. It just feels very inefficient and I don't like it"*. This guarding of access issue reveals an imbalance in power dynamics within the team (Nancarrow, et al., 2013; Morley and Cashell, 2017).

In contrast to PC17's experience, PC5 shared their experience of having access to the app platform. They (PC5) expressed how this access right afforded them the opportunity to develop a sense of independence, autonomy and competence to successfully fulfil their role within the interdisciplinary team in designing and developing the app. PC5 shared, *"If there are texts, or audios that need to be uploaded, we [health] were doing it ourselves... we just put the content inside the app. We had a content management system... I think they're good for independence. I felt like 'Oh, I'm independent. I'm uploading stuff myself' which was nice"*.

At the pragmatic level, differences in perspectives between industry and academia/research generally manifest as different interests and goals (Carlile, 2002; 2004; Stange, 2017). PC19 succinctly described, *"I think there's a disconnect and divide because research is more about advancing knowledge, whereas industry and commercial apps are more about making money"*.

Differences in interests and goals also arise between general members within interdisciplinary teams. PC21 shared, *"I think that that's the biggest thing for any interdisciplinary team, especially when you're all trying to move towards the same goal on a project. Because what the sub-set of goals that each team [member] has is often quite different, but as a team working together, these goals are supposed to culminate in the final product"*.

Relating to differences in interests and goals, another insightful finding was the pragmatic and political knowledge boundary issues that can arise between the project leader and the general team members. PC20 mentioned *"…sometimes the person in between [the knowledge broker] may have their own goals in terms of using different BCTs or persuasive or gamification techniques, and then there are subject experts [such as physical activity experts] who want things done another way. It can be difficult to communicate and negotiate. It's challenging, especially with limited project resources… it becomes quite a negotiation process"*.

#### 9.3.6.2 Overcoming Knowledge Boundaries

Interdisciplinary collaborating teams of mHealth physical activity intervention app projects need to address and overcome knowledge boundaries to effectively and efficiently carry out the process and achieve the project goals and objectives. Participants described three key ways of navigating and addressing knowledge boundaries within the interdisciplinary collaborating team (summarised in Figure 9.8): (1) *Team culture and dynamics*; (2) *Communication and negotiation*; and (3) *Using objects to facilitate knowledge sharing and shared understanding*.

***Team Culture and Dynamics***

*"Communication and making it a collaborative effort should be there from the beginning. I think that problems with these interdisciplinary collaborations arise when you think in phases and you think of one partner per phase instead of working together, communicating and collaborating in every phase of the process"*, stated PC30. Similar sentiments were voiced by PC29, who explained the importance of *"fostering communication and collaboration from the start so that it becomes part of the team culture and dynamics, so that people don't work in silos. But rather setting up the team from the beginning to be open to communication and collaboration. It'll make things a lot easier because it's embedded in the team culture"*. The significance of creating a healthy team culture in interdisciplinary teams has been emphasised in literature (Nancarrow, et al., 2013; Morley and Cashell, 2017; O'Reilly, et al., 2017).

Active listening, feedback and empathy were pinpointed by several participants. *"You have to be very patient and just listen"*, said PC4. PC10 said, *"You need to listen to everyone's side… listening is important"*. Similarly, PC2 conveyed, *"In the interdisciplinary team, you need to listen to everyone, even though they may a different perspective"*. Good listening skills have been reported in literature as imperative for successful interdisciplinary team collaboration (Nancarrow, et al., 2013). Together with active listening, some participants (PC3, PC29) discussed the value in creating *"a very good feedback culture"* in the team, where *"everyone can provide feedback and contribute new insights or perspectives that weren't yet considered"*. With regard to the interdisciplinary process in particular, PC2 expressed, *"Gathering feedback from the interdisciplinary team is important because you get all different types of views and opinions from people with different fields, which is really important"*. Moreover, PC1 spoke about the role of empathy in interdisciplinary team communication and collaboration.

In addition to active listening, feedback and empathy, a number of participants emphasised the significance of mutual respect within the collaborating team. PC2 stressed, *"It's vital to have an interdisciplinary team where you all respect and listen each other's different expertise"*. Respecting team members' heterogeneous backgrounds was also discussed by PC21 and PC28. PC21 also pointed out that *"sometimes when you have different perspectives [within the team], some people might accidentally undervalue what other people do, and I think that can be an unfortunate mistake within an interdisciplinary team. If you don't value them it's because you don't understand, so you need to educate yourself before having any strong opinions"*. PC28 shared an experience where they often feel undervalued and undermined, largely because they are unheard and disregarded as the only physical activity expert on their interdisciplinary team.

Hand-in-hand with the concept of mutual respect is trust and honesty (Nancarrow, et al., 2013). Interdisciplinary collaborating team members need to have trust in one another's knowledge, expertise, skills and roles within the team, and the various contributions offered to the mHealth physical activity intervention app project process and final output product (Morley and Cashell, 2017; O'Reilly, et al., 2017). PC21 and PC27 spoke about honesty and trusting other team members' ability to fulfil their responsibilities and trust that the timeframes they stipulate as necessary to perform those responsibilities are reasonable. In addition, PC21 drew links between team member characteristics and the overall team culture and dynamics. They (PC21) expressed, *"I think that self-awareness is also really important. A lot of issues I feel could be overcome by just being aware of who's in the team and I think self-awareness, trust,*

*communication, respect, honesty and valuing one another's contributions is key to the success of the team and project"*.

Team culture and dynamics can also be fostered by *"…creating a community [within the team] where people can contribute more interdisciplinary efforts, engage in regular contact, knowledge sharing and making it a learning experience for everyone"* (PC13). More broadly speaking, when working in international interdisciplinary teams, some participants spoke about embracing and learning about team members' different cultures (PC1, PC4, PC18). For example, PC18 described their learning experience about *"…developing an international mindset when working with different people with different backgrounds and cultures… and learning to be flexible when working with people who have different ways of working"*.

Along with these characteristics, PC2 emphasised that *"it's really important that we work with people who have the same kind of values, drivers and interests that we do"*. The significance of shared values, interests and goals is often emphasised as necessary for project success in interdisciplinary collaborating teams (Nancarrow, et al., 2013; Morley and Cashell, 2017). In touching on the pragmatic and political challenges between industry and academia/research, PC2 expressed, *"We've tried in the past to work with companies that have a very different philosophy in terms of wanting to commercialise apps and make lots of money. We've been really upfront about us having a public health philosophy and we're not in it to make lots of money, we're in it to help people get better health outcomes. If the companies don't have that same kind of value then it's caused real issues in the past. We make sure our values and interests are aligned. It's really critically important"*. PC11 also spoke about the importance of aligning interests and goals rather than *"getting caught up in the little limitations"* around funding and certain code not working. Instead, PC11 suggested that the team focus on the key purpose and vision of the project, and *"bringing [that] to the forefront of the project so that everyone works together towards that shared project purpose or goal"*. This was echoed by PC13 who emphasised, *"You need that common vision of where the project is going"*, and PC25 who stressed the importance of *"the interdisciplinary team… having a shared aim"*.

While most participants described the challenges frequently face in interdisciplinary mHealth physical activity intervention app projects, a small handful of participants shared positive experiences, largely owing to the time and effort put into fostering good team culture and dynamics. PC17 shared that they have *"been fortunate to work with people who understand my clinical background"* and that *"it usually takes time to get to know people initially, but after*

*a while, the process becomes smoother"*. Similarly, PC27 described working with people who they knew, respected and valued before forming the team and starting the project and that this positively contributed to a good team culture where their interests and goals were aligned, leading to the international success of the project.

***Communication and Negotiation***

Communication is essential and crucial for interdisciplinary teams to collaborate effectively and efficiently (Lakhani, Benzies and Hayden, 2012; Nancarrow, et al., 2013; Mayo, et al., 2016; O'Reilly, et al., 2017). All 31 participants highlighted communication as key and foundational to the success of mHealth physical activity behaviour change intervention app projects. For example, PC28 emphasised, *"I think communication is the biggest thing for a project to be successful, and at the same time a lack of communication can be the biggest downfall as well"*. *"Communication plays an important role"* expressed PC12, and *"It all boils down to communication throughout the process"* stated PC1. When faced with knowledge related challenges, *"Talk is probably the short answer. Just try and resolve it with talking"*, said PC22.

To establish channels of effective and efficient communication and negotiation within interdisciplinary collaborating teams, several participants discussed the importance and value in conducting regular team meetings and holding workshops; a notion supported by literature (O'Reilly, et al., 2017). PC11 stressed that *"open communication and regular team meetings are important"*, and PC26 said that *"everyone needs to be there for the team meetings, no separate secret meetings, so we're all on the same page"*. Holding interactive workshops and training sessions was also suggested by a few participants, where interdisciplinary team culture and dynamics can be fostered, and *"where everybody dedicates time to really flesh things out properly without being interrupted so that progress can be made"* (PC28). Furthermore, PC13 suggested, *"Getting the right people involved [in the project] with the same idea, and getting them working together, talking regularly and regularly discussing any issues at meetings is important"*. Additionally, with the operationalisation of app design features, PC14 discussed holding meetings with developers so that *"consensus opinions"* can be negotiated.

For effective and efficient intra-team communication, specifically in terms of language and terminology usage, participants generally suggested using *"simple language"* (PC14) and *"simple plain words"* (PC24) instead of *"using terminology that's relevant to your own*

*profession, you need to explain it at the level of, you know, fourth grade or sixth grade level"* (PC11). These sentiments were shared by other participants such as PC21, who stated that team members *"should be able to explain things in lay language, using plain simple language and not using the technical kind of jargon terms"*. A similar, albeit additive view was shared by PC2, who described *"the ability to convey complicated information to different groups of people in a way that makes sense to them is a very handy skill"*, and that understanding peoples' different backgrounds is necessary *"to convince people of things in their own language"*.

With regard to differences in language, jargon and interpretation of meaning, most of the participants emphasised the importance of speaking out and asking questions. PC23 said, *"If you don't understand each other, then just ask"*, and PC5 stated, *"Just ask, and don't be embarrassed to ask"*. PC1 shared, *"If there are different jargons, people are not afraid to speak up or to ask, and I think that's the most important thing in team collaboration"*. PC10 expressed *"Differences in jargon and terminology can be very challenging. You've got to ask the question and clarify with people, like 'What is that? What do you mean by that?' and getting people to articulate why things are important also tends to resolve issues pretty quickly"*. Moreover, PC16 stressed the value in asking questions to avoid exacerbating the division between technology and health team members, by *"asking for clarification. Because otherwise you create an even bigger divide between the tech guys and the health guys"*.

To further address differences in language, PC17 suggested *"establishing a common language between the health professionals and the developers. Without a common language things can become problematic in communication, so try may in advance to establish the common language to possibly mitigate issues that could come up or misunderstandings"*. This sentiment corresponds to Carlile's (2002; 2004) argument for developing a common language as a foundation for knowledge sharing processes between heterogeneous team members.

Notably, while differences in language present challenges, PC2 conveyed how language can also present opportunities, explaining, *"People have different strengths and different specialist language in communication, so they can go and do their broader communication in their own fields with stakeholders"*. Essentially, PC2 conveyed the notion that, for the interdisciplinary field of mHealth behaviour change intervention app design to progress and advance, more extensive dissemination across the relevant heterogeneous practice communities is necessary.

In terms of differences in perspectives, participants often discussed the various team members explicitly laying out and justifying their arguments, and through active listening, communication and negotiation, compromises and resolutions can be achieved. PC10 said *"I think it's honestly just taking a step back and asking 'What's their perspective for putting that point forward?'. 'What's their rationale?'. And doing the same on our end. A lot of times once you take a step back things become clearer and it's easier to reach an agreement about things, but you've also got to make compromises"*.

Differences in perspectives and good interdisciplinary team communication can also create opportunities for learning at the syntactic, semantic and pragmatic knowledge boundaries (Carlile, 2002; Nancarrow, et al., 2013; Melville-Richards, 2015; Stange, 2017). PC14 shared, *"There are times that we're teaching each other. Every time I've developed stuff, everyone feels like they've learnt a lot from each other"*. PC20 shared the same sentiment that every mHealth intervention app project *"is very much a learning experience that happens every time… and there's lots of negotiation"*. Similarly, in linking learning and language, PC9 stated, *"It's a learning experience for everyone, and learning how best to communicate and collaborate in the team with everyone from different backgrounds, and also end users. Because us health people have a language. Developers have a language. End users have a language. And all the other team members from marketing, design, behavioural science, all have different languages. Over time, the more we learn about differences in language, interests and goals, the quicker and smoother the process can go. It makes it easier for the project to be more successful"*.

To address differences in interests and goals at the pragmatic and political knowledge boundary, several participants emphasised the importance of bringing team members back to the core purpose of the project and using the defined project goals and objectives to guide the negotiation process. PC22 explained, *"It helps having a shared aspiration for the project and what you're hoping to produce"*. PC30 emphasised, *"Ultimately we have a shared purpose and we have a shared end goal. Sometimes the smaller objectives along the way might be different, like how the app will look, but at the end, we're all working towards the same end goal"*. Likewise, PC31 said, *"We have the same end goal. Maybe there's different ideas about how to get there in terms of design and development, but that end goal is the same for the whole team"*. In addition to this, another way to address pragmatic interest differences is to *"think about the cost of the project, and if someone wants to do something, does it fit with the project in terms of budget and time? There are often many different interests or competing goals on*

*what people want to see and develop [in an app], but there's consequences to that. So what are the costs? And if the cost is too high then it just won't happen"* (PC16).

At the pragmatic knowledge boundary, participants also discussed the role of communication and negotiation processes in addressing and resolving power status dynamics within the team, particularly pertaining to team members' stakes and trade-offs (Carlile, 2002; 2004). Balancing power dynamics is crucial in interdisciplinary collaborating teams (Nancarrow, et al., 2013; Morley and Cashell, 2017). Often people are unwilling or resistant to sacrifice their knowledge or interests (Carlile, 2002; 2004). PC16 touched on this: *"Creating an awareness that if you want to do one thing it often means there's going to be a sacrifice of something else"*. In addition, PC22 described the difficulties often faced when either health or technical team members are unwilling to change their minds about how the app can be optimally designed for end users. This usually occurs if an opposing view *"undermines the behavioural content of an app intervention"* or if *"there is a better way to design an app feature"*, in which case both sides are resistant to forgoing their power status and influence in the decision-making process.

An unwillingness to "trade-off" and "abandon" one's own knowledge and perceived power is a key pragmatic knowledge boundary challenge highlighted by Carlile (2004, p.557). PC24 provided confirmation of this challenge in practice. They (PC24) said, *"Everybody is an expert in their own slice [field], so they want to look good in the eyes of others. But you have to remove all of the myths about your own expertise and open up and show the simplicity of things underneath the surface. So you kind of lose a little bit of the glitter of your expertise. And people generally don't want to do that. People need to show their expertise by showing how simple it actually is, and risk losing some of that glitter, but it will help communication and collaboration in the team and will help the project to be successful"*. Essentially, PC24 is describing the pragmatic challenge where team members perceive their knowledge and power to be "at stake", which is usually met with resistance, but is essential and necessary for new knowledge to be created and for the interdisciplinary mHealth behaviour change intervention app field to advance and transform (Carlile, 2002, p.445; 2004; Stange, 2017).

***Using Objects to Facilitate Knowledge Sharing and Shared Understanding***

To address syntactic knowledge boundary issues concerning differences in language, and to facilitate knowledge transfer, most of the participants spoke about creating and using shared glossaries within the interdisciplinary collaborating team. PC16 spoke about *"putting together*

*a document where we put all of the keywords and explanations for what each key word was. Like a glossary so that team members had the terminology to refer to if necessary"*. Similarly, PC8 mentioned, *"We created a glossary of terms [that] was understood by all stakeholders"*. PC1 explained, *"We create our own glossary so it's clear for everyone. Like 'What is the user journey?' or 'What is the screen design?' or 'What is an interface?' and stuff like that"*. Some participants (PC2, PC26) discussed using Jira, PBworks and wikis as platforms for defining key terms and storing shared glossaries. Along with glossaries, some participants (PC3, PC26, PC29) mentioned creating shared abbreviation lists, particularly for teams where many abbreviations are used on a frequent basis. Though, in contrast, some participants said that they do not use shared glossaries, but expressed eagerness to use them in future. For example, PC20 said, *"No, no actually we don't use shared glossaries. That's actually a very good idea. It's something that might actually be very useful because it's a real problem"*. Glossaries are often acknowledged as valuable knowledge sharing artefacts in interdisciplinary collaborating teams (Fominykh, et al., 2015; Khisro and Persson-Slumpi, 2019).

To overcome differences in language, meaning and interests at the three syntactic, semantic and pragmatic knowledge boundaries, respectively (Carlile, 2002; 2004), interdisciplinary team members can employ written, graphical and practical methods to convey and share knowledge. At the syntactic level, PC15 described an experience where they asked the developers to *"write down"* the key technical terminology they were using. They (PC15) explained, *"Because I come from a public health perspective I did not have that [developer] language, just like the developer wouldn't have had my language to describe public health, so writing it down helped"*. At the semantic and pragmatic levels, using a graphical method, PC22 explained, *"Sometimes when developers don't understand why we as health scientists want something done a specific way, I'll do some like graphic design mock-ups for the developers. And try and drive them through the different scenarios so that they can see how some of the different design suggestions might impact on what we're trying to deliver through the intervention"*. Also using a graphical method, PC26 mentioned using *"pictures to help explain things"* and PC8 discussed using UML (unified modelling language) diagrams and elaborated, *"with a little bit of explanation, those diagrams can be easy for non-IT people to understand"*. Written and graphical objects are evidenced to support knowledge sharing in interdisciplinary collaborating teams (Carlile, 2002; Melville-Richards, 2015; Kinnunen, 2018).

Practical methods such as demonstrations and prototypes can help teams address challenges at all three knowledge boundaries, particularly the pragmatic level. PC23 said, *"We use some practical examples and demonstrations, and explain things step by step so that the other team members can understand"*. PC22 discussed the value in using demonstrations and prototypes as *"something tangible to interact with and see, so that we can better explain and understand different ideas and suggestions about how to improve the design. And then when the app is actually being built, and I've got a chance to see or use it. That provides a good basis because there's something tangible to discuss and negotiate around"*. The value of prototypes as tangible objects for mediating interdisciplinary collaboration was highlighted by PC12, *"We have different concepts on our heads, so the prototype gives us a tangible thing that you can get the communication around. So people can see, touch and feel the app, so you can figure out what you like and don't like".* Prototypes and other demonstrative artefacts are frequently reported in literature as effectively supporting interdisciplinary collaborating teams, particularly during co-design and co-development activities (Winkler, Huber and Dibbern, 2014; Kinnunen, 2018; Islind, et al., 2019; Gerling, et al., 2020; McCarthy, et al., 2020).

Other prototype and app design related objects identified by participants included the PSDM tables and the BCT taxonomies, which can be used to overcome knowledge boundaries. For example, PC20 mentioned, *"It's usually useful to define the minimum viable product (MVP) so that there is an absolute minimum set of requirements"*. In addition, PC21 discussed creating *"a core outcome set"* and PC24 mentioned creating *"a set of core features"*; both of which essentially fulfil the same purpose as the MVP and can be used to help define the project objectives and align the team members' goals. In addition, the four PSDM tables (summarised in Chapter 4, Section 4.4.2) were identified by PC24 as *"a communication vehicle between different stakeholders participating in the process of designing a [physical activity] app, because it provides a common ground to start talking about the app will be designed and defines a language that people from different fields can adopt and use to speak to each other"*. Furthermore, PC7 discussed the value in applying the BCT taxonomies as an object for making sure that the same language is used to refer to specific intervention strategies and BCTs, which is particularly useful during the mHealth physical activity app collaborative design process.

Maintaining up-to-date project and team documentation throughout the project process were also discussed by participants as useful objects for addressing knowledge related challenges and recording team decisions. PC16 described project and team documentation as a *"crucial*

*thing"* for stipulating the roles of each team member and their responsibilities. They (PC16) also spoke about the value in recording and documenting the minutes of team meetings to *"solidify decisions, to make things concrete by capturing them, so that we don't revise and re-explore things that we've already made decisions on"*. PC28 also discussed the importance of *"documenting discussions because we tend to forget why we made certain decisions early on in the project, and then you get to the end of the whole process and say 'God, why did we do that?'. So documenting that entire process is super important because there would have been a valid reason for why you made that decision in the first place and you don't want to forget what that was when you get to the end"*. On another note, PC27 emphasised that *"the most important thing [is] project and team planning [and] to be very clear on the prenup, so you know that this person does this, this and this, and that person does that, that and that"*. They (PC27) also underscored the importance of planning *"resources with respect to funding and time"*, and described how effective planning makes the project process significantly smoother. This view was echoed by PC31, who described the value in *"good project management"* and *"clearly dividing the work packages, so that every team member knows what every other person is responsible for in the team"*. Documentation is often reported in literature as valuable for supporting knowledge sharing practices (Melville-Richards, 2015; Stange, 2017).

#### 9.3.6.3 Knowledge Brokering

Knowledge brokering plays an integral role in helping interdisciplinary collaborating teams share knowledge and address and overcome knowledge boundaries (Meyer, 2010; Clarke, et al., 2012; Rushmer, et al., 2019). When discussing knowledge brokering practices, participants discussed the role of a knowledge broker and the knowledge brokering process, and the way this aids the development of shared understandings between collaborating team members from heterogeneous backgrounds (Figure 9.8).

***Knowledge Brokering and Creating Shared Understandings***

The concept of a knowledge broker was described by several participants when asked who is responsible for facilitating knowledge sharing and supporting shared understandings between the interdisciplinary collaborating team members. A knowledge broker assumes a neutral and impartial role as an intermediary and translator of knowledge betwixt the team members from heterogeneous practice communities (Rosenkranz, Vranešić and Holten, 2014; Filip, 2016); a concept introduced and discussed in Chapters 5 and 7.

When discussing knowledge related challenges, particularly between people in health and people in technology, PC11 highlighted that *"there's a real big disparity in terms of how these two universes work. Tthere is a need to have someone who brokers between them. Those people who have skills to slightly understand this and slightly understand that, and can convey knowledge between them"*. PC26 referred to this person as a *"translator"* between health and technology. *"People like health informaticians are translators,"* PC26 elaborated, *"They have enough knowledge about the IT and IS side of things to be able to communicate with the software developer, but not so much that they can develop the system themselves. The same with health. The health informatician knows enough health language to be able to communicate with health practitioners in their own language. And then being that translator between those two groups. So they're not necessarily specialists or experts in either side, but they have enough knowledge to translate. So it's about putting things in their language, in terms that they can understand on both sides"*. This description of a translator is conveyed in literature on the role and function of knowledge brokers (Rosenkranz, Vranešić and Holten, 2014; Van Enst, 2018).

PC20 shared the same views, and referred to knowledge brokers as *"the people in between"*. PC20 expressed, *"Having everyone in the interdisciplinary team on the same page and working towards a common goal really needs the people in between. The people in between know some of the expertise of other people, but aren't full experts in one area. So they stand in between and help improve that communication and collaboration. And they help create that shared understanding between people in the team"*. In this case, PC20's concept of *"the people in between"* is congruent with the responsibilities of knowledge brokers discussed in literature (Blackman, Kennedy and Ritchie, 2011; Haas, 2015). Similarly to the notions held by PC11, PC20 and PC26, PC13 described themselves as a *"de facto leader"* and as someone who assumes the position as *"the liaison, the diplomatic one that listens to everyone's different point of view and tries to translate the jargon and different perspectives between them"*. PC13's reference to the knowledge broker as a form of "liaison", who holds a neutral position and assumes responsibility for facilitating knowledge sharing, is conveyed in knowledge brokering literature (Haas, 2015).

When asked who assumes this knowledge brokering role, all participants identified the project manager/leader, product manager, team leader or principal investigator, depending on the context and practical experience of their involvement in mHealth physical activity intervention app projects. Referring to the project lead as a knowledge broker is documented in literature

on interdisciplinary teams (Clarke, et al., 2012). In terms of participants' responses, PC10 shared, *"Typically on these projects, I am the project lead. So it comes to me to navigate issues around communication, collaboration and knowledge sharing between people in the team"*. PC11 referred to the principal investigator as assuming the knowledge brokering position.

A few participants touched on some other responsibilities of knowledge brokers in fostering good team culture and dynamics, such as respecting one another's different knowledge and expertise. PC21 said, *"The people/person leading the project should be able to communicate the importance and value of each team member. It's really important so that certain people within the team aren't undervalued"*. This corresponds to the knowledge broker's role in managing the culture, dynamics and power relations within the team (Haas, 2015).

Lastly, with regard to creating shared understandings within interdisciplinary collaborating teams on mHealth physical activity behaviour change intervention app projects, PC15 described the project leader (the knowledge broker) as being *"responsible for getting the ball rolling"* on facilitating shared understanding within the project team. To create shared understanding within an interdisciplinary team, PC15 explained, *"We need to have this conversation early on in the project. When it comes from the top person [knowledge broker] down it's a lot easier… to make sure everyone understands each other and to develop this kind of shared understand in the team of what the goals are, the expectations and understanding of what person in the team is doing and contributing. But often the leader does not lead it"*. These responsibilities of the knowledge broker in creating shared understanding from early on and throughout the project is recognised and discussed in knowledge brokering literature (Clarke, et al., 2012; Rosenkranz, Vranešić and Holten, 2014; Gomes and Tzortzopoulos, 2018).

### 9.3.7 Main Theme 7: Key Challenges and Opportunities for Future Improvement

Given the newly "emerging interdisciplinary" nature of the mHealth behaviour change intervention app space, literature reports several key challenges, lessons learned and opportunities (Ben-Zeev, et al., 2015; Blandford, et al., 2018; 2019a; 2019b; Gao and Lee, 2019; Taj, Klein and van Halteren, 2019, p.1; Guo, et al., 2020; Sucala, et al., 2021). All 31 participants discussed key challenges pertaining to mHealth physical activity behaviour change intervention app projects and teams, the lack of sufficient funding, the evolving interdisciplinary mHealth app field in general, the divide between academia and industry, and offered recommendations for future opportunities. Most of the challenges reported by the

participants have been reported on and documented in literature. Figure 9.9 provides an illustrative summary of the key challenges and opportunities.

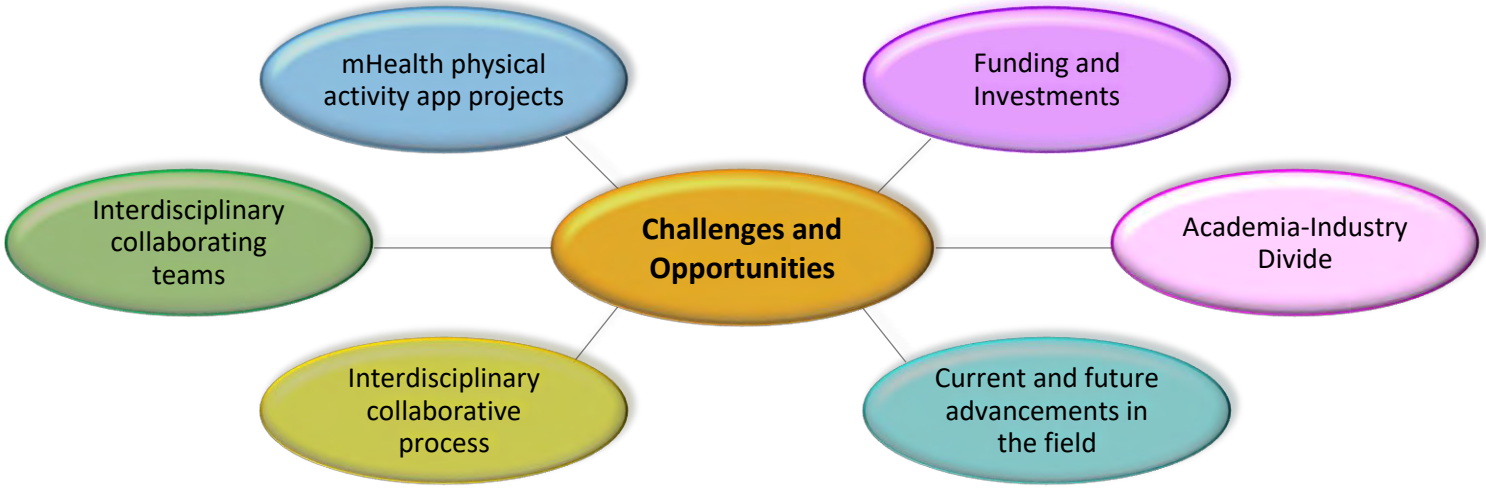



*Figure 9. 9: Key Challenges and Opportunities for Future Improvements (Main Theme 7): Interview Study Findings [Source: Researcher's own construction]*

***mHealth Physical Activity Behaviour Change Intervention App Projects***

For mHealth physical activity projects, concerns about the assumptions often held by academics and researchers were highlighted by some participants, particularly assumptions about what the real world problems are and what intervention content and app design features end users will respond to positively. PC14 expressed, *"In research we can have a very naïve view of developing mHealth app technology products. We can get carried away and it might not be a product anyone wants. We might create this beautiful and educational product assuming people will use it, but it's maybe something nobody cares about, so they won't use it"*. Other participants described similar experiences where *"only at the end of the process when we evaluated the app did we find out it didn't meet their requirements. The assumptions we made were wrong, so the end users didn't use the app"* (PC21). Another issue often associated with research is *"blue sky thinking [where] there's so many big new ideas and you can get carried away and struggle to make final decisions about the app"* (PC16). This ultimately has consequences on the mHealth app project scope, resource demands and timeline.

From a more technical perspective, challenges are often faced when developing mHealth physical activity apps intended to operate smoothly across various mobile (smartphone and

tablet) devices and software platforms. PC14 explained, *"It's really hard to create an app that's robust across so many different devices, especially with Android… it's really tricky"* and provided an example of an app working on some users' Samsung Galaxy S8s, but not others. Some participants also noted challenges with connecting, pairing, accessing and exchanging data between mHealth physical activity apps with other physical activity devices, trackers and smart watches (PC21, PC28, PC30). In addition, the standards, policies and guidelines stipulated by Android OS and Apple iOS with regard to user interface design, material and component design, architecture, privacy and security, and quality assurance can present challenges for designers and developers when maintaining the lifespan of commercially released apps. PC9 explained, *"Your app can be perfectly functional today, but then Apple or Google will go and make some changes to the platform or whatever and then your app doesn't work. It's like they can break your app by flipping a switch"*. This particularly becomes a problem when trying to keep an app up-to-date after being released on the commercial app market, and when trying to conduct long-term RCTs since the stringent freeze requirements prevent any app modifications or updates, thus impeding and possibly halting the RCT.

Physical activity as the intended target behaviour is multidimensional and complexly interwoven with peoples' daily lifestyles and their psyches, attitudes, behaviours and routines. PC15 spoke about the myriad of ways physical activity can be incorporated in peoples' lives, the countless ways people can be active daily and maintain active lifestyles, and the various ways activity can be measured, evaluated and monitored. This is made more complex by peoples' personal preferences, cultures, socioeconomic standing, interests and values, and the way these characteristics influence what people find meaningful in terms of physical activity, intervention content design and app feature design. This adds to the challenge of creating sustainably effective mHealth physical activity intervention apps. PC23 pointed out, *"There's no one-size-fits-all intervention solution with physical activity, we need to focus on more personalised solutions"*. A few other participants also pointed out challenges associated with developing mHealth physical activity apps that are appropriately designed for reaching disadvantaged, lower-income and special needs communities, and despite the opportunities afforded by mobile app technology, there remain obstacles in effectively helping those target audiences. The desire to be more inclusive and to reach and help more people in various settings and contexts was expressed by participants in both academia/research and industry.

In terms of mHealth physical activity app intervention content design, participants conveyed conflicting views on the use of theory. Some participants spoke about the need for more theory-based interventions, and the need for commercial apps to have more theory incorporated into their intervention content design. While others expressed the desire to move away from a heavy reliance on theory, although not to completely repudiate theory, but to distance from traditional theoretical models, build new theory, and be more open to learning from industry, which seldom relies on traditional theory to change individuals' physical activity behaviours. Similar conflicting views and opinions have been published in literature (Hagger and Weed, 2019).

***mHealth Physical Activity App Projects: Interdisciplinary Collaborating Teams***

The most prominent challenges associated with interdisciplinary collaborating teams in mHealth physical activity behaviour change intervention app projects pertains to knowledge, and the knowledge boundaries faced on syntactic, semantic and pragmatic levels. The key knowledge related challenges were discussed in Subsection 9.4.6, and will not be reiterated in detail. Essentially, team and knowledge challenges are interwoven, and largely concern the chasm between health and technology, and the need to build stronger bridges to manage and overcome different perspectives, language, interpretations of meaning, expectations, interests, goals, and ways of working, thinking and approaching problems and solutions. Community of practice and boundary object theory (Chapter , Sections 5.3.1 and 5.3.2) stresses the need for boundary workers (collaborating team members) to move beyond the boundaries of their own localised practice communities, in order to enter into the shared (interdisciplinary) boundary space betwixt the relevant heterogeneous communities. Within these shared boundary spaces, interdisciplinary collaborating teams are able to engage in boundary crossing activities that enables the valuable sharing of diverse knowledge, expertise, resource and skill sets, therefore progressing and advancing the mHealth intervention app space. This view was echoed by PC19, who expressed, *"There needs to be collaboration between the different disciplinary experts so you're getting diverse perspectives and skill contributions, which will improve the design, development and effectiveness of physical activity apps hugely"*.

The need for competent knowledge brokers, who are weakly linked to several heterogeneous communities of practice, yet are full members of none (described in Chapter 5, Sections 5.3.2 and 5.3.3), was repeatedly articulated by participants. Some key characteristic requirements of these knowledge brokers include: an ability to understand, speak and translate different practice community language; to guide, facilitate and mediate heteropraxial activities; be good leaders;

be able to make concrete final decisions; engage well in negotiation and conflict resolution practices; and to be strong *"champions"* of their mHealth physical activity app projects. Knowledge brokers are also responsible for establishing and managing the team culture and dynamics, clearly defining project specifications and team member roles and responsibilities, and managing political and power dynamics within interdisciplinary collaborating teams.

***mHealth Physical Activity App Projects: Interdisciplinary Collaborative Process***

An effective and efficient interdisciplinary collaborative process is imperative to the success of a mHealth physical activity intervention app project. The main interdisciplinary collaborative process challenges were discussed in Section 9.4.4, and will not be reiterated in detail. In essence, the main process challenges concern the key differences in the process steps and activities generally performed in industry versus those performed in academia/research. The academic process generally involves more steps, is slower and tends to undergo fewer iterations due to funding, time and resource constraints, than the industry process. A major challenge associated with the academic process concerns traditional RCTs, which from a scientific perspective are required to demonstrate rigorous evidence of effectiveness, whereas industry practitioners are not required to carry out long-term RCTs. Given the limitations with RCTs, several adaptive, pragmatic and ecological trial designs have been proposed in the mHealth intervention app space (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Mohr, et al., 2015; Collins, 2018). Yet challenges are faced in that the validity, credibility and reliability of these non-traditional methods are often questioned and opposed by traditional scientific sceptics. This makes it difficult for more progressive academics/researchers when attempting to perform adaptive and microrandomised trials as well as when trying to secure funding and publishing the trial findings in accredited journals.

Several participants, both in academia/research and industry, voiced the need for more co-design and participatory design approaches to the interdisciplinary collaborative process. PC1 succinctly stated, *"We need to be even closer to the users"*, and PC15 expressed, *"Customer engagement needs to be front and centre of the process and customers [end users] must be involved throughout the entire process".* These approaches were argued as better meeting the needs and preferences of target end users. *"In the end, you produce a product that actually meets consumer needs"*, stressed PC15. *"We need to involve the end user all the way through… so we wind up with a product that the people you're targeting are much more likely to pick up and use, and hopefully help change their physical activity behaviour"*, explained PC22.

Furthermore, participants in both academia/research and industry expressed the need for less siloed process steps and activities, and more cross-disciplinary communication and collaboration so that the team works collectively throughout the duration of the project process.

All of the interview participants practising in academia/research expressed the need to improve the interdisciplinary collaborative process. More specifically, the desire to speed up, reduce the full duration, and increase the number of prototyping iterations in the process. These desires are strikingly challenging to achieve given the weighty requirements in academia, specifically activities regarding project research proposals, funding and investment applications, ethics applications and approvals, RCTs, and formal dissemination and publishing. On the other side, in industry, there is an ongoing effort to remain flexible, open and adaptive to constantly improving the process and continuously updating commercial physical activity apps.

An insightful finding was two participants' (PC3, PC30) mention of the desire to create some objects that will make it easier to carry out specific stages and activities in the process. PC3, who works purely in industry, explained, *"We're looking at having tools and processes in place to support people. For example, in the discovery phase [of design thinking] we want to have some tools, methods and different processes that you can use in the discovery phase. You may or may not use them, you don't have to use them, but you can grab and run with them, to make it easier and quicker to do the discovery activities"*. PC30, who works primarily in research (but has experience in collaborating with industry), shared *"There needs to be more open access open source components for when you want to design and develop [physical activity] apps. So if we want to create a game [in the app] we can reuse components. Or if we have an idea to create a just-in-time adaptive intervention, then we can save time if there's already tools that exist to make it easier to connect the app and sensor. Of course we'll still need someone with programming knowledge to bring it all together, but instead of starting from scratch every time, we could reduce the time needed to develop the app if we could reuse open source components"*. Essentially, PC3 and PC30 are describing creating objects and supporting artefacts that can be referred to and used to help guide team members when carrying out their responsibilities during the process, and can help speed up the design and development process. These responses by PC3 and PC30 fundamentally evidences and corroborates this research project's thesis argument for the need for objects and supporting artefacts to help guide and support interdisciplinary collaborative teamwork practices.

***mHealth Physical Activity App Projects: Funding and Investments***

The most strongly articulated and emphasised challenge reported by participants practising in academia and research was the lack of funding and investments for mHealth intervention app projects. Participants repeatedly stressed the challenges faced in acquiring funding as well as challenges faced with the insufficient supply of funding in the short and long term. *"Funding is a problem with all projects"*, stated PC9. While larger projects are usually connected with sufficient, albeit often not enough, funding, smaller projects are generally always affected. PC15 voiced, *"For smaller projects, there's a lot less money dedicated to it, a smaller number of people and less time, so it just gets dragged out for years… you're trying to find money, but it's hard to secure sometimes, especially for smaller projects"*. In contrast, PC15 explained, *"For larger projects with large amounts of funding, those projects usually run quite smoothly"*.

Funding challenges are faced at various stages of the project process. From the start of the project, when teams are formulating and planning the project, funding obstacles present a double-edged sword. On the one hand, some participants spoke about needing to run preliminary studies to identify and provide evidence of a real world problem in order to develop their project proposals and applications for funding and grants. On the other hand, funding is needed to conduct these preliminary studies, and hence funding is needed before formal funding applications can be submitted. Similar challenges arise with RCTs. Teams require funding to conduct pilot studies to gather evidence for acceptability and feasibility, the results of which are then used to apply for additional funding to conduct long-term RCTs. Some participants also spoke about projects halting at stages of the process due to a lack of funding.

Insufficient funding was repeatedly reported to effect the number of design-test-refine prototyping iterations teams could conduct during the process. PC28 shared, *"In research we're limited by money, resources and time, so although we would like to conduct more iterations, it's not possible most of the time"*. PC20 expressed, *"We're often short on money and time, and we've promised the funder that we'll do some type of evaluation at the end, so then we have to cut the process short and we can't iterate as many times as we'd like"*. The number of iterations is often cut shorter when academic/research groups have outsourced software development to external companies, in which case each iteration poses significant costs. PC7 shared, *"If we outsource the development of the app to a company, they have rules with how many changes they can make. Ideally, I would make the process quite iterative until the evaluation phase, but given logistic constraints, sometimes that's not feasible"*.

Funding and investment challenges are also faced when academics and researchers attempt to initiate mHealth physical activity intervention app projects that are perceived as too risky, which can be with regard to the methods used or the product design solution ideas. In terms of methods, along with oppositions faced by progressive researchers in conducting and publishing on adaptive, pragmatic and ecological trial designs, there are challenges faced in finding adequate funding for such trial designs. In addition to this, teams can often face challenges in obtaining funding for projects where the product design ideas are perceived as too high risk, usually due to their innovative nature. PC28 explained, *"More innovative ideas are seen by funders as more risky. But in this field with the rate of technological advancements, we need to be thinking 10 years ahead almost, not only thinking about what we can develop with technology today but what technology we'll have in the next 10 years. So, like everyone's talking about voice-based AI right, that it's going to be the next big thing, but I mean finding funding for innovative ideas like that is harder because it's more risk, right? So we need someone who trusts us to take those risks and funds us to try these innovative solutions"*.

***mHealth Physical Activity App Projects: The Divide Between Academia and Industry***

The challenges associated with the divide between academia/research and industry have been revisited and elaborated on several times in the findings discussions. The main differences pertain to the process and knowledge aspects of mHealth physical activity app projects. With regard to the process, the academic process is generally *"a long involved process"* (PC14) whereas the industry process is significantly quicker and more iterative. Furthermore, on the side of academia/research, participants have described the main interests as having *"more of a human goal, to improve health and help society"* (PC28), *"to help people get better health outcomes"* (PC2), and to *"advance knowledge"* (PC19). On the side of industry, participants generally described the main *"goal is to make money"* (PC28). Interestingly though, when interviewing participants practising purely in industry, their individually expressed goals and intentions are to *"help people live healthier and more active lives"* (PC1). Although these participants also acknowledged the larger corporate strategic goals to *"connect people to the brand"*, their personal interests do not conflict with the goals held by academics/researchers. Commercial companies, as entities, obviously have a main profit goal (Liu, eta l., 2019; Ford, et al., 2021), but it would seem that for many individuals working within these companies, they value helping people lead more active and healthier lifestyles.

Challenges also concern the need for better academic-industry collaborations, and the translation and commercialisation of mHealth physical activity behaviour change intervention apps. Some participants discussed the need for academic projects to be more sustainable and to collaborate with industry to develop revenue models that allow apps to be continually updated and improved over time. This is needed in academia/research considering that the funding for maintaining commercially released apps tends to run out after finishing RCTs, leading to the app becoming unsupported, outdated and obsolete. Interestingly, the intention of many academics/researchers to develop business and revenue models that will allow for profit generation in order to prolong the lifespan of commercially released apps tends to overlap with the goals of industry. This demonstrates that despite academics/researchers strongly expressed stance against industry profit goals, they understand the importance of revenue models and value them as secondary and supplementary project goals. Their secondary revenue goals are to maintain and prolong the lifespan of the commercially released app products, rather than to generate significant profits that are *"exploitative"* (PC27).

***Current and Future Advancements in the mHealth Physical Activity Behaviour Change Intervention App Field***

A notable challenge and opportunity frequently identified by participants concerns the lack of sustained engagement and long-term effectiveness of mHealth physical activity intervention apps. *"How to really engage people for a longer period? That's something that still needs to be figured out"*, stated PC1. This was echoed by PC19, *"The engagement with physical activity apps is quite low. People might start using an app and then they'll stop"*. Several studies have reported on the short-term use and effectiveness of physical activity apps (generally between two to three months), and highlight challenges associated with long-term sustained usage and effectiveness (Romeo, et al., 2019; Mitchell, et al., 2020; Truelove, et al., 2020).

With advancements in digital technology, concerns and challenges have arisen regarding tracking capabilities, data privacy and security, and the unethical use of persuasive system design technology and dark patterns (Gao and Lee, 2019; Haque, 2020; Luguri and Strahilevitz, 2021). PC1 explained, *"…it's a topic of ethical awareness. So we don't want to push too much into gamification and persuasion because making people too dependent on our products [physical activity apps] isn't what we want. People spend a lot of time anyway on screens. So it's really about how can we make people more active instead of getting them always in front of their phone. We want to do something good"*. This was echoed by PC29, who expressed,

*"From a product and design perspective, we're trying to be good citizens in a sense that we're not using any dark patterns... That's something we are trying to avoid"*.

Another challenge concerns the going improvements and changes to platforms and devices that the apps are connected to, which impacts an app's functionality. PC14 shared, *"For our [app product name], it's an app available on commercial app stores. And it's kind of now at the end of its lifespan. Not because it's broken, but it's about to break because of Facebook changes… and we don't have the funding to update it".* Furthermore, there are changes to legislative and regulatory standards and policies that affects the design, development and sustainable lifespan of apps. For instance, several participants spoke about the European Union's GDPR, which needs to be adhered to (discussed in Subsection 9.4.5.8).

Challenges and opportunities also arise with regard to current and future innovations, particularly with the drive towards leveraging just-in-time adaptive interventions, wearables and smart sensors, machine learning, deep learning and artificial intelligence (Arigo, et al., 2019; Chew, Ang and Lau, 2021). A few participants emphasised the need for more innovation, particularly in academic/research projects; however, the main challenge with initiating such projects circles back to funding and investment challenges, and perceptions of innovative ideas as being higher risk. PC28 explained, *"One of the challenges we have is keep up pace with new innovations. So keeping up with changes and big companies that have millions and millions of dollars to design innovative, amazing things"*. The challenge presented with securing funding for innovative projects is compounded by the challenge concerning the prolonged academic process. *"It's a huge challenge"*, reported PC28, *"...because we're also trying to create something that's super innovative and up-to-speed, but by the time we go through the whole process, already what we've done is out of date. So the process needs to be more rapid, but we also need better funding for more risky projects and better collaboration with industry"*.

Along with challenges and opportunities presented by current and future innovations, there are challenges and opportunities regarding ongoing advancements and fundamental shifts in society. For instance, several participants discussed how the COVID-19 pandemic affected their projects and completely changed the way they approached their formative testing and trial studies; a phenomenon reported in recent literature (Porter and Hook, 2020; Vargo, et al., 2020; Dodds and Hess, 2021). PC11, for example, discussed how the COVID-19 pandemic pushed their team to conduct their *"first full virtual trial ever, from the recruitment, data collection,*

*you know, all the trainings, focus groups, interviews, everything was virtual"*. Elaborating, PC11 said, *"So yeah, the world's changing, it's changing very quickly"*.

Given the ongoing advancements in society and the emerging interdisciplinary mHealth physical activity behaviour change intervention app arena, a handful of participants discussed the need to change and restructure education systems and training programs. *"There really is a need to invest in a society where our education systems are not so disparate. It's like, 'Oh, you're in health and I'm in tech, we're different people'. Well, actually no, it's not in the real world. Technology has creeped into all aspects of our daily lives. It's not siloed anymore, it's a broader society thing, a life thing. Really much needs to be done with the chasm between health and technology, or technology and non-technology disciplines because in today's society these things are increasingly interwoven in harmony. Our education systems need to reflect that"*, explained PC11.

### 9.3.8 Thematic Relationships

There are interdependent, entangled and interwoven relationships between all of the main thematic findings of the interview study. In other words, multiple bidirectional and multidirectional complex thematic relationships exist between the *mHealth physical activity behaviour change intervention app projects* (main theme 1), *the goals and objectives* (main theme 2), *the actors* (main theme 3), *the interdisciplinary collaborative process* (main theme 4), *the objects and supporting artefacts* (main theme 5), and *the knowledge practices* (main theme 6). These complexly interwoven and intricately entangled relationships were discussed extensively in Chapter 7, and have been empirically evidenced and interpersonally verified through participants' interview responses. The most conspicuous evidence for the complex thematic relationships are apparent when participants answered questions regarding one specific theme, they would incidentally discuss other themes. For instance, when asked a question about the process, they would incidentally discuss other themes, including the project, goals and objectives, actors, objects and supporting artefacts, and knowledge. Alternatively, when asked a question about actors, their response would include mentions and explanations of the project, goals and objectives, and knowledge.

For example, when asked to identify and describe the main steps and activities of the process, PC14 responded, *"If I think back to the process we used for [app product name], it was a major project with the objective of developing a gamified physical activity intervention that connects*

*users to each other via Facebook. So in the process there was formative research with interviews with target end users to get their ideas on what the app should do and look like"*. Another response by PC14 stated, *"Then we'd go through the design process and then we'd do alpha testing and beta testing to get user feedback from the intervention participants, using interviews or focus groups"*. Essentially, in just these two excerpts, PC14 covered themes on the project, goals and objectives (specifically the project goals and objectives), process steps and activities (namely the formative research and iterative design, development and formative testing stages), actors (namely the end users), as well as objects and supporting artefacts (specifically supporting methods).

As another example, when asked a question about overcoming knowledge boundaries, a small part of PC9's response was, *"In most projects we end up on the same page, but we really are speaking different languages. But after a while we figure out some of the programmers' language. What's important is being very clear and upfront at the start of the process and explaining to the programmers what the objectives of the project are, that it's not a typical commercial app"*. In this case, PC9 is simultaneously touching on the project, goals and objectives, knowledge, process and actors themes.

Overall, in essence, the project and its goals and objectives have an impact on which interdisciplinary team members are recruited, the interdisciplinary process conducted, the objects and supporting artefacts employed, and the knowledge sharing practices engaged in throughout the project process. Likewise, depending on the individual team members, the defined project goals and objectives and the prescribed process steps and activities, a variety of objects and supporting artefacts may be used at different stages of the process, either to share knowledge within the interdisciplinary collaborating team or to communicate with other actor subthemes (such as external stakeholders or end users). In short, there exist multiple intricate and complex thematic relationships between all of the main themes and subthemes.

## 9.4 Conclusion

This chapter has given an overview of the research participant information and has provided a thorough and detailed discussion of the interview study findings. To revisit the purpose of conducing these virtual semi-structured interviews, the main empirical study research question asked: *"What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the*

*mHealth physical activity behaviour change intervention app context?"*. Based on the finding discussions and the supporting evidence presented by quotation excerpts and relevant literature citations, it can be concluded that the main empirical study research question has been answered. Figure 9.10 provides a summary overview of the main thematic findings from the interview study.

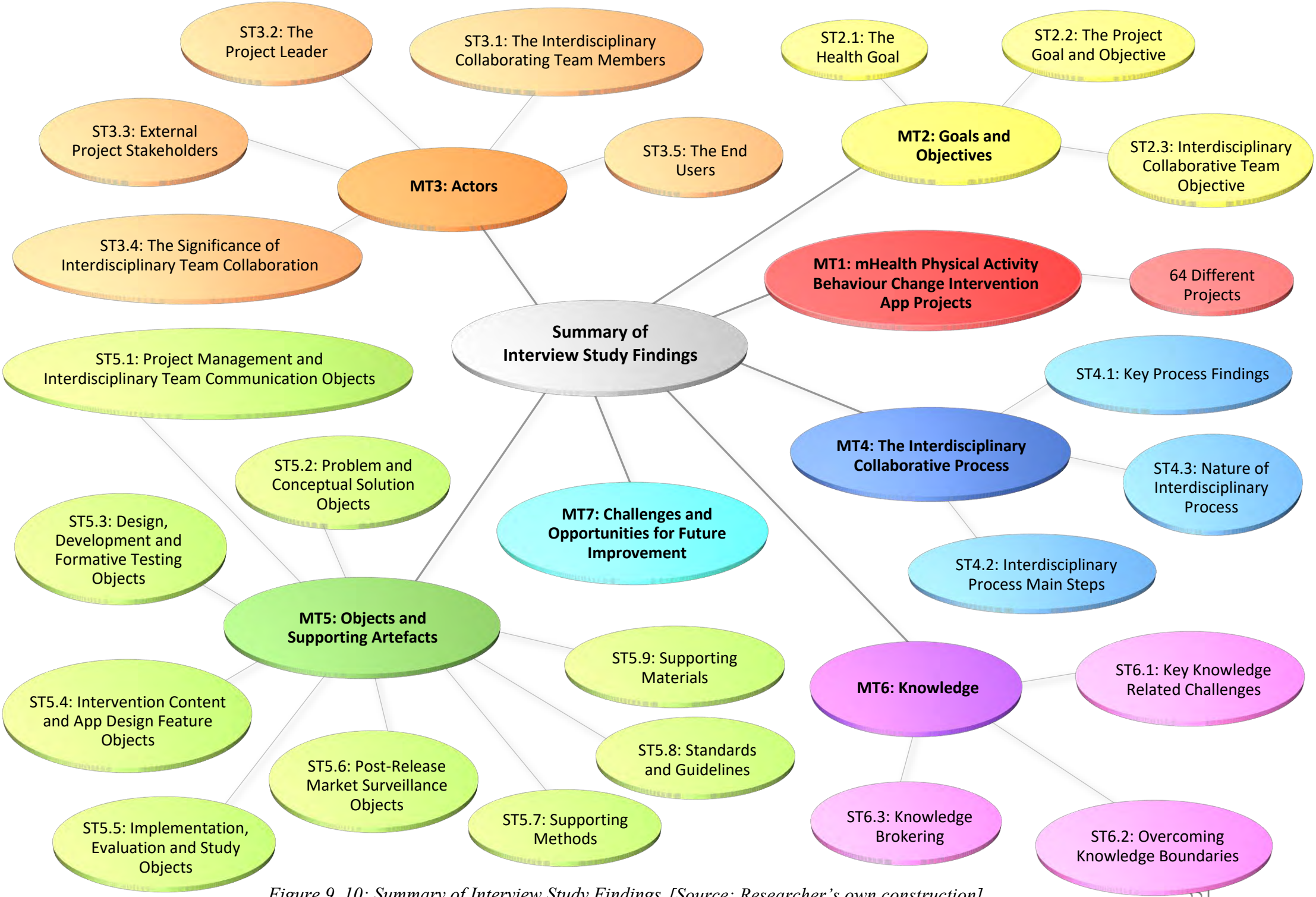


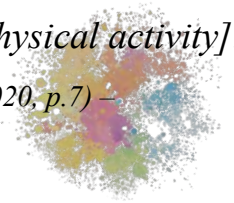

*Figure 9. 10: Summary of Interview Study Findings [Source: Researcher's own construction]*

# Chapter 10

## An Enhancement of the Interdisciplinary mHealth App Design Framework

*The development of evidence-based digital tools is complex, as they should be guided by theoretical frameworks, and requires large interdisciplinary teams with competence in technology, behavioural science and lifestyle-specific areas [such as physical activity].*

*– Bendtsen, et al. (2020, p.7) –*



## 10.1 Introduction

The empirical study conducted with knowledgeable and experienced academic researchers and industry practitioners from a diversity of relevant backgrounds (communities of practice) yielded valuable contextual findings that can be used to revise and enhance the proposed Interdisciplinary mHealth App Design Framework. As part of the process of building a conceptual framework, a "capacity for modification" allows new findings to inform iterative reconceptualisations and adjustments that strengthen the framework's quality and trustworthiness (Jabareen, 2009, p.58). In DSR, developing and producing a good quality artefact that demonstrates rigour and relevance is an iterative endeavour involving continuous design cycles and evaluations against a set of criteria (Herselman and Botha, 2015; Hevner, et al., 2018). In this research study, a set of evaluation criteria is used to revise and enhance the Interdisciplinary mHealth App Design Framework.

This chapter first outlines the framework revision process, which incorporates an evaluation criteria assessment. The revisions to the framework's main components and subcomponents are presented in a structure similar to Chapters 7 and 9, thus providing a comparative parallel between the proposed framework, the evaluation study findings, and the revised and enhanced framework. The modifications made to each component are illustrated by an accompanying diagram. Thereafter, the overall structure revisions of the enhanced framework for guiding the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps is presented. This is followed by the conclusion that future demonstration applications of the framework can provide further refinements, enhancements and generalisations of the framework to the physical activity domain as well as other modifiable health behaviour change domains (such as healthy eating and sleep).

Figure 10.1 illustrates the iterative construction and revision of the framework, which predominantly falls within Step 3 ("development") of the DSRM (outlined in Chapter 2), although, the pre-determined set of evaluation criteria and evaluation study findings are drawn from Step 4 ("evaluation"). Circumscription knowledge flows through the iteration cycle, which essentially validates the contextual and practical relevance of the artefact and knowledge contribution (Vaishnavi and Kuechler, 2008; Vaishnavi, Kuechler and Petter, 2017). This chapter contributes to answering the fourth research sub-question: *"What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary*

*collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?"* and also answers the main research question: *"How can interdisciplinary teams collaborate in the design, development and evaluation of mHealth physical activity behaviour change intervention apps?"*.

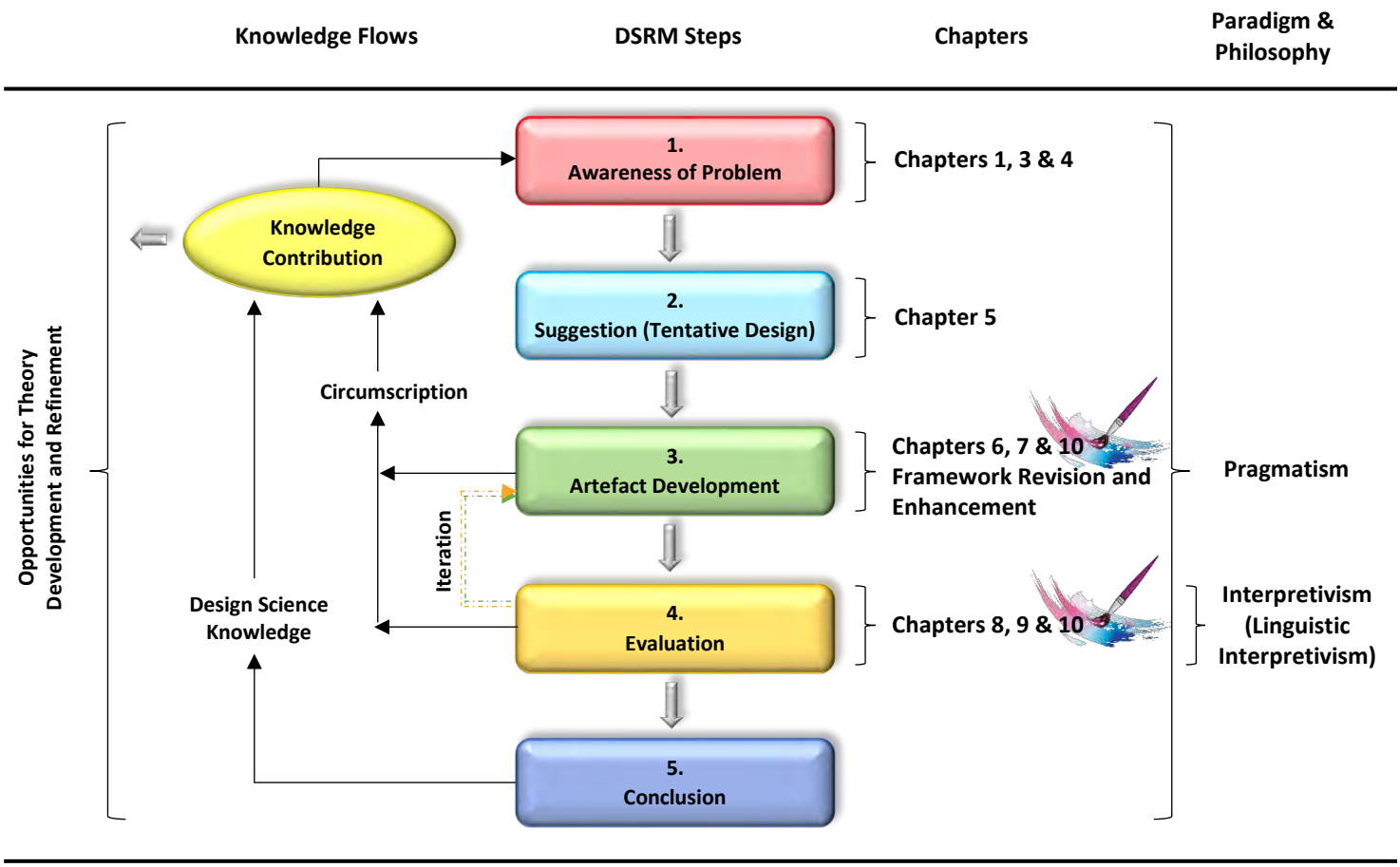



*Figure 10. 1: DSRM: Artefact Revision: Enhancing the Proposed Framework Using the Evaluation Criteria and Evaluation Study Findings [Source: Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 10.2 Framework Revision Process

In this research study, the set of evaluation criteria outlined in the evaluation methodology (Chapter 8) is used as an evaluation criteria assessment template for comparing the proposed framework (Chapter 7) with the evaluation study findings (Chapter 9), in order to determine which framework components and subcomponents require revision. Subsequently, enhancements to the proposed conceptual framework are applied based on the empirical study findings.

To briefly recap for purposes of lucidity (detailed descriptions in Chapter 8, Subsection 8.2.2.1), the three evaluation criteria are: (1) *construction adequacy*; (2) *language adequacy*; and (3) *clarity*. The first criterion, *construction adequacy*, requires that the framework provide comparative accuracy for researchers and practitioners relevant to the real world problem and solution environment/domain (Schütte and Rotthowe, 1998). The second criterion, *language adequacy*, requires that the semi-formal (artificial) language and terminology applied in the framework be suitable, comprehensive and accurate for researchers and practitioners in terms of the (mHealth physical activity app) application domain (Schütte and Rotthowe, 1998). The third criterion, *clarity*, requires that the framework's hierarchical decomposition and elemental and informational arrangement and interrelation (layout design) be comprehensive and explicit (Schütte and Rotthowe, 1998). For all three criteria, the aim is to reach *adequate* consensus agreement and ontological domain representation through interpersonal verification with the findings from academic researchers and industry practitioners interviewed in the evaluation study. Achieving definite, absolute and complete consensus agreement and ontological domain representation is impractical and unattainable given the complexity and emerging nature of the real world problem and solution space (Schütte and Rotthowe, 1998).

To use the three evaluation criteria as a template for comparing the proposed framework (Chapter 7) with the interview study findings (Chapter 9) so that the quality of each component (and its subcomponents) can be assessed, and the framework can be revised accordingly where necessary, an evaluation criteria-revision matrix has been developed. The matrix, provided in Table 10.1, maps the *three evaluation criteria* with *four revision states* (no revisions, minor revisions, moderate revisions, major revisions). Whether a component or subcomponent requires any revisions or not in terms of each of the three evaluation criteria depends on the comparative discrepancies between the proposed framework and the interview study findings. In cases where no revisions are required (green), the current state of the proposed framework (Chapter 7) remains the same. In cases where minor, moderate or major discrepancies are identified, the proposed framework (Chapter 7) undergoes minor (yellow), moderate (orange) or major (red) revisions, respectively, using the interview study findings (Chapter 9). Illustrative diagrams are provided of each enhanced component (and their subcomponents). Moreover, lessons learned and new additions from the findings of the interview evaluation study are noted, and their revision state impact on the enhanced framework is identified. At the end of the revision process, the enhanced framework artefact that adequately meets all three criteria for all of its comprising components and subcomponents is presented.

*Table 10. 1: Evaluation Criteria-Revision Matrix [Source: Researcher's own construction]*

| | Revision State | | | |
|---|---|---|---|---|
| **Evaluation Criteria** | **No Revisions** | **Minor Revisions** | **Moderate Revisions** | **Major Revisions** |
| **Construction Adequacy (CA)** | CA | CA | CA | CA |
| **Language Adequacy (LA)** | LA | LA | LA | LA |
| **Clarity (CL)** | CL | CL | CL | CL |

## 10.3 Revisions to the Interdisciplinary mHealth App Design Framework

### 10.3.1 Revisions to Main Component 1: Actors

Overall, the framework's first main component, *"actors"*, required moderate revisions. The initial conceptual framework's *"actors"* component was largely accurate in terms of construction adequacy, and only required minor revisions in terms of language adequacy (such as slight terminological changes) to more accurately suit and reflect real world research and industry practice. The main moderate and major revision changes made concerned the clarity, and particularly the hierarchical decomposition and elemental and informational arrangement and interrelation (layout design), of the heterogeneous interdisciplinary collaborative team communities. As for lessons learned from the interview study findings, "health psychology" could be removed, and the "health community" and a separate "psychology community" could be formed. Given that both "health" and "psychology" contribute directly to the intervention content of mHealth physical activity apps, they remain within the same community. A new addition was the *"research community"*, which generally includes research administrators, centres, groups, clinical staff/field experts and social scientists team member roles (Table 9.4). Researchers were recognised in the initial proposed framework, but not as a stand-alone community. Table 10.2 provides an overview of the revisions to the *"actors"* component (and its subcomponents).

*Table 10.2: Evaluation Criteria Assessment and Revisions to the Framework's Main Component 1: Actors [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| Interdisciplinary Team | Interdisciplinary Collaborative Team | CA | LA | CL | • Moderate overall hierarchical decomposition and elemental rearrangements of interdisciplinary collaborative team (Figure 10.2).<br>• Addition of "collaborative" term. |
| Team Lead and Project Management<br><br>Primary Empirical Study Facilitation | Principal Investigator<br><br>Product VP/ Manager<br><br>Project Manager(s)<br><br>Team Leader(s)<br><br>Researchers | CA | LA | CL | • Addition of "principal investigator" term as the project lead role in academia/research.<br>• Addition of "product VP/manager" term as the project lead role in industry/commercial practice.<br>• "Researchers" term replaces "primary empirical study facilitation" role to lead and manage primary empirical studies.<br>• Rearrangement of "principal investigator", "product VP/manager", "project manager(s)", "team leader(s)" and "researchers" hierarchical decomposition, arrangement and interrelations (Figure 9.4).<br>• Distinction between academic, academic-industry collaboration, and industry projects (Figure 9.4).<br>• Resizing of knowledge broker actor icons: "principal investigator" and "product VP/manager" as the biggest actor icon; "product manager(s)" and "team leader(s)" as the two middle size actor icons; and "researchers" as the two smaller size actor icons – depicting status. |
| Health Behavioural Intervention Community | Health and Psychology Community | CA | LA | CL | • Removal of "behavioural intervention" term to abstract health community roles.<br>• Addition of "psychology" term to community.<br>• Change of "health behavioural change intervention sciences" to 'health sciences".<br>• Addition of "content team" and "public health" (Table 9.2).<br>• Absorption of "public health" with "health promotion".<br>• Addition of "personal trainer" and "exercise physiologist" as "health behaviour specialist domain" examples (Table 9.2).<br>• Addition of "sports, exercise and other psychology" team member roles (Table 9.2). |
| Information Systems Community | Information Systems Community | CA | LA | CL | • Addition of "health informatics" team member role (Table 9.2).<br>• Decomposition and elemental rearrangement change of "human computer interaction, user-centred and user experience design" and "cognitive and usability engineering" to "user experience design and usability engineering".<br>• Removal of "systems" term from "systems and software engineering".<br>• Removal of general "information systems".<br>• Absorption of "persuasive technology and game development community", and elemental change to "persuasive systems design" and "game design" team member roles. |

| | | | | | |
|---|---|---|---|---|---|
| Business and Product Development Community | Business, Marketing and Product Development Community | CA | LA | CL | • Addition of "marketing" term to community.<br>• Addition of industry related business team member roles, including "quality assurance", "product management" and "customer relationship management" (Table 9.2).<br>• Absorption of "product design and development" with "product management".<br>• Absorption of "business development" with "product management, design and development".<br>• Removal of "consumer" from "consumer and mobile app marketing".<br>• Addition of "economics" and "law" team member roles (Table 9.2). |
| Computer Sciences Community | Computer Sciences and Data Analytics Community | CA | LA | CL | • Addition of "data analytics" term to community.<br>• Removal of general "computer sciences".<br>• Elemental and informational adjustment of "mobile software development and mobile app servers" to "mobile and app development".<br>• Addition of "networking" term to "mobile app architecture, infrastructure and networking" (Table 9.2).<br>• Addition of "game development", rearranged from "persuasive and game" community.<br>• Absorption of "game development" with "mobile and app development".<br>• Addition of "machine learning and artificial intelligence" team member roles (Table 9.2).<br>• Addition of "mobile app database and engineering" (Table 9.2).<br>• Removal and rearrangement of "open-source software consultants" to "external stakeholders".<br>• "Data analytics and DevOps" absorbs "data and statistics" team member roles, becoming "data analytics, statistics and DevOps" (Table 9.2). |
| Persuasive Technology and Game Development Community | Information Systems Community | CA | LA | CL | • "Persuasive Technology and Game Development Community" absorbs into "Information Systems Community".<br>• Informational adjustment to "persuasive systems design" and "game design" roles. |
| Third Party Stakeholders | External Stakeholders | CA | LA | CL | • "External" replaces "Third Party" term.<br>• "Mobile, wireless and software app companies" changes to "commercial companies and consultants" term (Table 9.3).<br>• "Commercial companies" absorbs "data analytics and DevOps companies and consultants".<br>• Addition of "other" to "health behaviour specialist and other consultants" (Table 9.3).<br>• Addition of "steering committees" (Table 9.3).<br>• Addition of "community and groups" to "healthcare and community organisations and groups" (Table 9.3).<br>• Addition of "government officials" (Table 9.3).<br>• "Government officials" absorbs "policy makers, legislative and regulatory officials".<br>• Addition of "marketing companies and consultants" (Table 9.3). |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | • Absorption of "marketing companies and consultants" with "commercial companies and consultants".<br>• Absorption of "open-source software consultants" (from "computer science and data analytics community") under "open-source software providers".<br>• Addition of "creative designers, writers and language specialist consultants" (Table 9.2). |
| End Users<br><br>(Target Population Group Representatives) | End Users<br><br>(Target Population Group Representatives) | CA | LA | CL | • Hierarchical decomposition and elemental extensions to "direct" and "indirect" end users.<br>• Two extensions to "direct" including "end users as official project stakeholders" and "co-design or participatory design process" (Figure 9.5).<br>• Two extensions to "indirect" including "specific stages of the process" and "end users as study participants" (Figure 9.5). |
| **Lessons Learned and New Additions** | | | | | |
| - | Research Community | CA | LA | CL | • Addition of *"research community"* to *"interdisciplinary collaborative team"*.<br>• Addition of "research project management and administration", "research centres and research groups", "researchers and PhD projects", "clinical trial staff and field experts", and "social scientists" team member roles (Table 9.2). |
| - | Significance of Interdisciplinary Team Collaboration | CA | LA | CL | • Lessons learned regarding the significance and importance of interdisciplinary team collaboration further verified and evidenced the thesis argument and proposed framework. |

Based on the construction, language and clarity (layout design) revisions, Figure 10.2 provides an enhanced diagram of the Interdisciplinary mHealth App Design Framework's first main *"actors"* component (updated from Figure 7.4), which now sufficiently meets all three evaluation criteria. Figure 10.3 provides a detailed depiction of the actors holding *"knowledge boundary brokering roles"*, clarifying distinctions between academia/research, industry/commercial practice, and academia-industry collaboration projects. Figure 10.4 provides a detailed illustration of the *"end users"* community. Both figures drawn from Chapter 9 are modified.

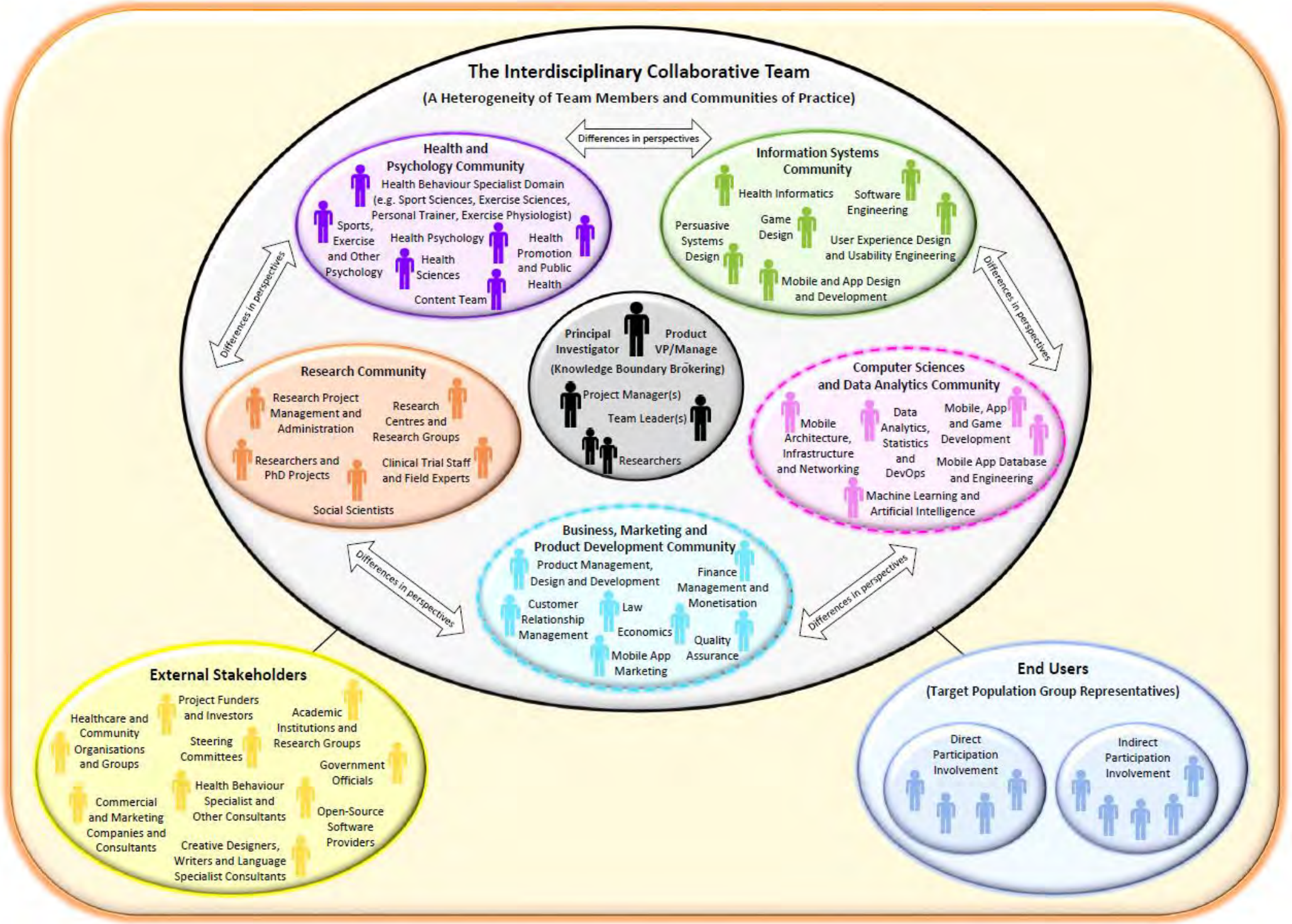



*Figure 10. 2: Enhanced "Actors": Main Component 1 of the Revised Framework [Source: Researcher's own construction]*

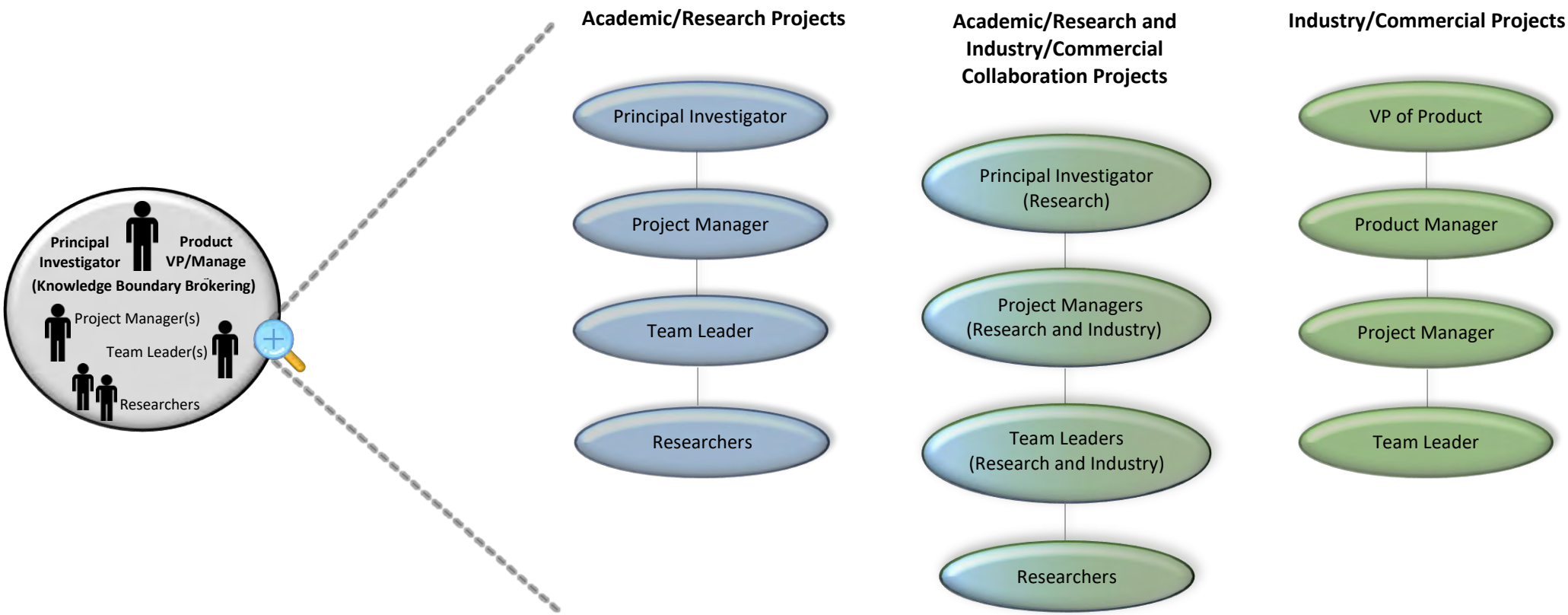



*Figure 10.3: Enhanced "Actors": Detailed Perspective of Knowledge Boundary Brokering Roles [Source: Researcher's own construction]*

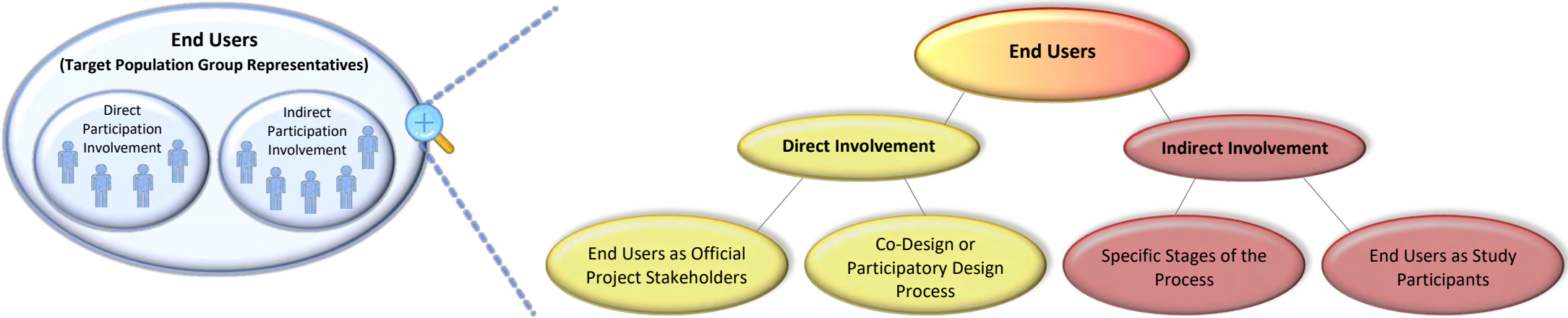



*Figure 10.4: Enhanced "Actors": Detailed Perspective of End Users [Source: Researcher's own construction]*

### 10.3.2 Revisions to Main Component 2: Interdisciplinary Collaborative Process

Overall, the framework's second main component, *"interdisciplinary collaborative process"*, required moderate to major revisions. The initial conceptual framework's *"process"* component was mostly accurate in terms of construction adequacy, language adequacy and clarity. With regard to the process steps and activities, Steps 1, 2 and 8 required only a few minor revisions and Steps 5 and 7 required some minor and moderate revisions. In comparison, Steps 3 and 4 required the most major revisions, particularly in terms of clarity and the hierarchical decomposition and elemental and informational and interrelation of the steps. Another major elemental and informational rearrangement was the addition of *"Step 6: Ecological Trials and Process Evaluation"*, which necessitated construction adequacy and language adequacy modifications to the initial proposed framework. In general, the existing activities within the various process steps of the initial proposed framework were largely confirmed through interpersonal verification; it was more so that the hierarchical and decomposition modifications required these existing activities to be rearranged.

Table 10.3 provides an overview of the revisions to the *"interdisciplinary collaborative process"* component, covering the process characteristics, nature and main steps and activities. Table 7.3 forms the basis of Table 10.3, which includes revisions informed by the interview study findings (Table 9.4). Based on the interview study findings, the initialisms are lessons learned on the differences between research and industry processes. As for the initialisms: (R/A) corresponds to process steps and activities predominantly performed in research and academic projects; (I) corresponds to process steps and activities predominantly performed in industry and commercial projects; and (R/A) (I) conveys process steps and activities performed in both research and industry projects. After the revisions, the modified *"interdisciplinary collaborative process"* main eight steps include, namely: (1) *Project and Team Formalisation*; (2) *Problem Understanding and Formative Research*; (3) *Ideation and Conceptualisation*; (4) *Iterative Design, Development and Formative Testing*; (5) *Optimisation and Summative Evaluation*; (6) *Ecological Trials and Process Evaluation*; (7) *Deployment and Release*; and (8) *Post-Release Market Surveillance and Continuous Improvement*.

Based on the interview study findings, lessons have been learned with regard to the increasing use and popularity of optimisation trials and ecological momentary assessments as appropriate to the mHealth physical activity intervention app context, the opportunities and challenges of

academia-industry collaborations, the notable differences between academic and industry processes, the increasingly desire for and use of co-design and participatory design processes incorporated in the overall project process, and the use of existing approaches in current practice. The main new process step addition included ecological trials and process evaluation.

*Table 10. 3: Evaluation Criteria Assessment and Revisions to the Framework's Main Component 2: Interdisciplinary Collaborative Process [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| **Interdisciplinary Collaborative Process Characteristics and Nature** | | | | | |
| Process Characteristics | Process Characteristics | CA | LA | CL | • "Interdisciplinary" and "collaborative" were interpersonally verified as vitally important to the success of a mHealth intervention app project process |
| Process Nature | Process Nature | CA | LA | CL | • Structure informational and language revision from "systematic" to "somewhat systematic".<br>• Structure informational and language revision from "non-linear" to "somewhat linear".<br>• "Iterative", "flexible", "cyclical", "feedback looping", "adaptable", "continuous" and "reflective" interpersonally verified/confirmed.<br>• "Theory-based" and "evidence-based" interpersonally verified/confirmed.<br>• Addition of "co-design" and "participatory" design process nature for "direct" end user involvement. |
| **Interdisciplinary Collaborative Process Steps and Activities** | | | | | |
| **Step 1:** Project and Team Formalisation | **Step 1:** Project and Team Formalisation | CA | LA | CL | • Added election of "principal investigator" and "product VP/manager" (Figure 10.3).<br>• "Researchers" replaces "primary empirical study facilitators" term (Figure 10.3).<br>• Addition of "team building" (Table 9.4).<br>• Addition of "steering committee appointment" (Step 1, A/R, Table 9.4).<br>• Addition of "ethics" (Step 1, A/R, Table 9.4).<br>• Addition of "business strategy" and "business KPIs" to "business plan" (Step 1, I, Table 9.4).<br>• Addition of "team task allocation plan".<br>• Absorption of "Project and Team Formation" activities (Step 1, A/R, I, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Step 1, Table 7.3). |
| **Step 2:** Problem Understanding | **Step 2:** Problem Understanding | CA | LA | CL | • Addition of "Formative Research" to Step title.<br>• Addition and absorption of "Literature and Market Review" (Step 2, Table 9.4).<br>• Addition of "formative research" activities (e.g. focus groups) (Step 3, A/R, Table 9.4). |

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| | and Formative Research | | | | • Addition of "business problem (consumer problems)" and "business problem statement" activities (Step 3, I, Table 9.4).<br>• Absorption of "Problem Understanding and Formative Research" activities (Step 3, A/R, I, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Step 2, Table 7.3). |
| **Step 3:** Theoretical and Conceptual Base Solution Development | **Step 3:** Ideation and Conceptualisation | CA | LA | CL | • "Ideation and Conceptualisation" term replaces "Theoretical and Conceptual Base Solution Development" and "Instantiated Conceptual and Technological Solution Design" step titles.<br>• Hierarchical decomposition and elemental rearrangement of "Step 3.1: Theoretical Base", "Step 3.2: Conceptual Base" and "Step 4: Instantiated Conceptual and Technological Solution Design" all absorbing into "Ideation and Conceptualisation" (Table 7.3).<br>• Addition of "design sprints" and "prioritise ideas" activities (Step 4, I, Table 9.4).<br>• Absorption of "Ideation and Conceptualisation" activities (Step 4, A/R, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Steps 3 and 4, Table 7.3). |
| **Step 4:** Instantiated Conceptual and Technological Solution Design | **Step 4:** Iterative Design, Development and Formative Testing | CA | LA | CL | • "Iterative Design, Development and Formative Testing" replaces "Instantiated Concrete Solution Design and Development" step title.<br>• Elemental rearrangement by merging "Instantiated Concrete Solution Design and Development" and "Formative Evaluation" (Steps 5 and 6, Table 7.3).<br>• "Alpha Testing" replaces "Pilot Testing" term.<br>• Addition of "Pilot Testing" after "Beta Testing" – adopting health interpretation of term.<br>• "Pilot Testing" absorbs "Pilot Testing and Improvement" activities (Step 7, A/R, Table 9.4).<br>• New formative testing sub-steps: (4.1) Alpha Testing; (4.2) Beta Testing; (4.3) Pilot Testing.<br>• Not all formative testing steps are mandatory.<br>• Addition of "quality testing/quality assurance" and "debugging" activities (Table 9.4).<br>• Addition of "design sprints" (Step 5, I, Table 9.4).<br>• Absorption of "Iterative Design, Development and Testing" activities (Step 5, A/R, I, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Steps 5 and 6, Table 7.3). |
| **Step 5:** Instantiated Concrete Solution Design and Development | **Step 5:** Optimisation and Summative Evaluation | CA | LA | CL | • "Optimisation and Summative Evaluation" replaces "Formative Evaluation" step title.<br>• Absorption of "Summative Evaluation" activities (Step 8, Table 7.3).<br>• Addition of "optimisation" activities (Step 6, A/R, Table 9.4).<br>• Choice between conducting "optimisation" activities (e.g. MOST and SMART) and/or "controlled trial" activities (e.g. RCT).<br>• Absorption of "Optimisation" (Step 6), "Controlled Trial" (Step 8), "Follow-Up" (Step 9), and "Modification and Updates" (Step 11) steps and |

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| | | | | | activities into "Optimisation and Summative Evaluation" (A/R, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Step 8, Table 7.3). |
| **Step 6:** Formative Evaluation | **Step 6:** Ecological Trials and Process Evaluation | CA | LA | CL | • Addition of "Post-RCT Trial and Process Evaluation" activities (Step 10, A/R, Table 9.4).<br>• Addition of options to apply "pragmatic trials", "ecological momentary assessments".<br>• Addition of "process evaluation" activity. |
| **Step 7:** Deployment | **Step 7:** Deployment and Release | CA | LA | CL | • Addition of "Release" term to step title.<br>• Absorption of "Implementation, Rollout and Release" activities (Step 12, A/R, I, Table 9.4).<br>• Addition of "translation and commercialisation process" activities (A/R).<br>• Addition of "licencing and contract" activities (A/R, I).<br>• Addition of "shipping" activities (A/R, I).<br>• Addition of "dissemination with marketers and campaign" activities (A/R, I).<br>• Verification of existing business, monetisation and marketing activities (Step 7, Table 7.3). |
| **Step 8:** Summative Evaluation | | CA | LA | CL | • Absorbs into Step 5 "Optimisation and Summative Evaluation".<br>• Interpersonal verification/confirmation of existing activities (Step 8, Table 9.4). |
| **Step 9:** Post-Release Market Surveillance and Continuous Improvement | **Step 8:** Post-Release Market Surveillance and Continuous Improvement | CA | LA | CL | • Addition of "issue tracking" activities.<br>• Addition of "customer/consumer support" activities.<br>• Addition of "product, KPIs and business strategy/goals alignment" to business activities.<br>• Absorption of "Publications" activities (Step 13, A/R, Table 9.4).<br>• Absorption of "Post-Release Market Surveillance and Continuous Improvement" activities (Step 14, A/R, I, Table 9.4).<br>• Interpersonal verification/confirmation of existing activities (Step 9, Table 7.3). |
| **Lessons Learned and New Additions** | | | | | |
| - | Optimisation versus Controlled Trial activities | CA | LA | CL | • Lessons learned on the option between applying optimisation (MOST, SMART) trials and/or controlled trials (RCTs).<br>• Optimisation, if adopted, is carried out before a long-term RCT.<br>• Optimisation trials are increasing in practice use, but face resistance from traditional views.<br>• Verification and confirmation of challenges and limitations of controlled trials (RCTs) in the mHealth intervention app environment/context.<br>• Optimisation (MOST, SMART) was recognised in initial proposed framework, but not as integrated in the overall process. |
| - | Ecological Momentary Assessments (EMAs) | CA | LA | CL | • Addition of "Ecological Trials and Process Evaluation" as Step 6 in the *"interdisciplinary collaborative process"*.<br>• Lessons learned regarding the increasing use and popularity of EMAs, notably appropriate to the mHealth physical activity intervention app |

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| | | | | | environment/context (Kim, et al., 2019; Zapata-Lamana, et al., 2020; Ponnada, et al., 2021). |
| - | Academia-Industry Collaborations | CA | LA | CL | • Lessons learned on the opportunities and challenges of academia-industry collaborations (e.g. conflicting timelines and priorities).<br>• Lessons learned regarding the need for better collaborations between academia and industry. |
| - | Differences between Academic and Industry Processes | CA | LA | CL | • Lessons learned on the key differences between multi- and interdisciplinary processes used in academia versus industry.<br>• Academia (in comparison to industry): more mandatory process steps; longer overall process; more official loops to jump through (e.g. project proposals, funding applications and ethical approval); bigger emphasis on long-term rigorous controlled trials (e.g. RCTs); risk of obsolescence; more difficulties with securing sustained funding/investment; and a higher emphasis on publications. |
| - | Co-Design and Participatory Design | CA | LA | CL | • Lessons learned regarding the emphasis on incorporating "co-design" and "participatory design" processes (with end users) in the overall interdisciplinary collaborative process.<br>• "Co-design" and "participatory design" with end users was recognised in initial proposed framework, but not as frequently integrated and amalgamated with overall process. |
| - | Use of Existing Approaches | CA | LA | CL | • Lessons learned on the use of existing multi- and interdisciplinary digital health intervention development approaches (Chapter 6).<br>• Lessons learned on the frequently referenced use of the five-step "design thinking" process. |

Based on the construction, language and clarity (layout design) revisions, Figure 10.5 provides an enhanced diagrammatical illustration of the Interdisciplinary mHealth App Design Framework's second main *"interdisciplinary collaborative process"* component (updated from Figures 7.5 and 7.6), which now sufficiently meets all three evaluation criteria.

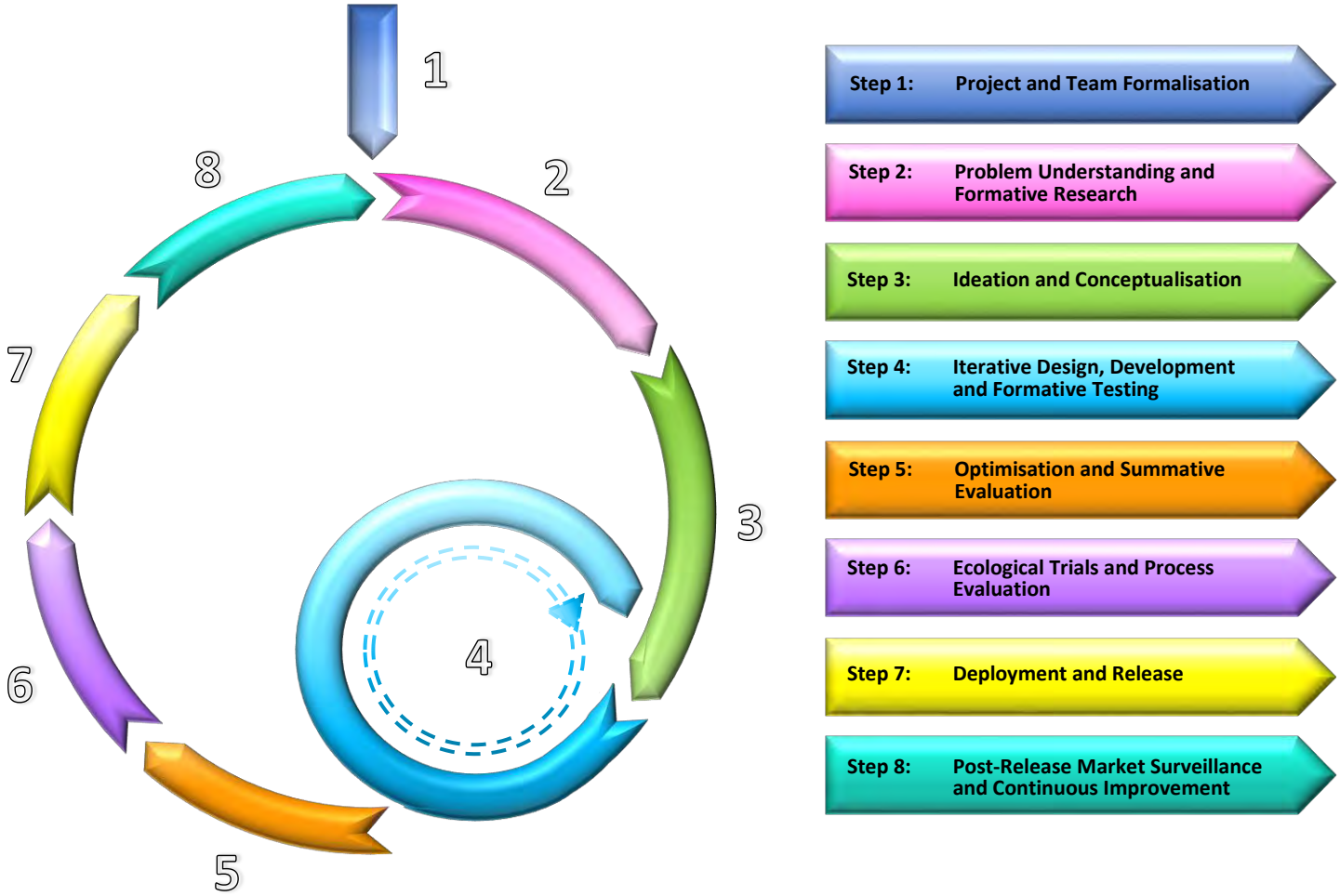



*Figure 10.5: Enhanced "Interdisciplinary Collaborative Process" (Main Process Steps): Main Component 2 of the Revised Framework [Source: Researcher's own construction]*

### 10.3.3 Revisions to Main Component 3: Boundary Objects and Supporting Artefacts

Overall, the framework's third main component, *"boundary objects and supporting artefacts"*, required major revisions – the most revisions of all the framework components. In general, the construction adequacy of the *"boundary objects and supporting artefacts"* component was accurate and relevant to real world practice, and the language adequacy and clarity of the supporting artefacts only required a few minor revisions. However, the language adequacy (terminology of categories and types) and clarity (hierarchical decomposition and elemental arrangement and interrelation) of the boundary objects required full revisions based on the interview study findings. The marked difference in language adequacy and clarity was mainly due to the proposed framework being developed through the tri-composite theoretical lens, which used boundary object theory that the interview study participants were not familiar with,

and hence the initial boundary object categories (primary, secondary and tertiary) and types (design and general) did not match real world research/academic and industry/commercial practice. Instead, there was a preference to refer to boundary objects in terms of the interdisciplinary collaborative process steps, which became a valuable and vital lesson learned, and led to major revisions. Another lesson learned was that researchers/academics and industry/commercial practitioners prefer to refer to objects and artefacts through the provision of real world examples, which contributed valuable context relevant information to the framework. For example, naming specific software and tools used during the process.

Table 10.4 provides an overview of the revisions to the *"boundary objects and supporting artefacts"* component (and its subcomponents). The revised boundary object and supporting categories include, namely: (1) *Project Management and Interdisciplinary Team Communication Objects*; (2) *Problem and Conceptual Solution Objects*; (3) *Design, Development and Formative Testing Objects*; (4) *Intervention Content and App Design Feature Objects*; (5) *Deployment, Evaluation and Study Objects*; (6) *Market Surveillance and Continuous Improvement Objects*; (7) *Supporting Methods*; (8) *Standards and Guidelines*; and (9) *Supporting Artefacts and Materials*.

Noticeably, despite the interview participants not being aware of boundary object theory, the term "boundary" has deliberately not been revised or removed from the framework's main component title. The term, however, has been removed from the boundary object categories to cater for real world practice use and comprehensibility. The justification for not revising the main component title is to remain true to the tri-composite theoretical framework and proposed suggested solution (DSRM, Step 2 in Figure 10.1). The definitions, descriptions and three template contributions (on core properties, characteristics and nature qualities) therefore remain part of the framework's *"boundary objects"* superclass; although, their availability is for optional review, and interdisciplinary collaborating team members are no longer required to understand the theoretical concepts (which is a key change from the initial proposed framework).

*Table 10. 4: Evaluation Criteria Assessment and Revisions to the Framework's Main Component 3: Boundary Objects and Supporting Artefacts [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| Primary Design Boundary Objects | Project Management and Interdisciplinary Team Communication Objects | CA | LA | CL | • "Project management and interdisciplinary team communication objects" replaces "primary design boundary objects".<br>• Objects apply to all process steps.<br>• Addition of "project and team management tools and software" (Table 9.5).<br>• Addition of "interdisciplinary team communication tools/platforms" (Table 9.6).<br>• Addition of "project and team management objects", "presentation tools/software", and "project, team and process documentation" (Section 9.3.5.1).<br>• Absorption of some "secondary design boundary objects" and "secondary general boundary objects" related to project, team and process management (Figure 7.8).<br>• Interpersonal verification/confirmation of some secondary boundary objects (Figure 7.8). |
| Primary General Boundary Objects | Problem and Conceptual Solution Objects | CA | LA | CL | • "Problem and conceptual solution objects" replaces "primary general boundary objects".<br>• Addition of "problem objects" (Section 9.3.5.2), applies to process step 2.<br>• Addition of "ideation and conceptual objects used within team" (Section 9.3.5.2), applies to process step 3.<br>• Addition of "formative research, ideation and conceptualisation objects with external stakeholders" (Section 9.3.5.2), applies to process step 3.<br>• Absorption of "literature artefacts" from "other supporting artefacts and materials" (Figure 7.8).<br>• Absorption of some "tertiary design boundary objects" and "tertiary general boundary objects" (Figure 7.8) relevant to problem, formative research, and ideation and conceptualisation.<br>• Interpersonal verification/confirmation to some tertiary boundary objects (Figure 7.8). |
| Secondary Design Boundary Objects | Design, Development and Formative Testing Objects | CA | LA | CL | • "Design, development and formative testing objects" replaces "secondary design boundary objects".<br>• Addition of "design objects and artefacts" (Table 9.7), applies to process step 4.<br>• Addition of "development objects and tools" (Section 9.3.5.3), applies to process step 4.<br>• Addition of "formative testing objects and tools" (Table 9.8), applies to process step 4.<br>• Addition of "connecting devices and branding objects" and "quality assurance objects" (Section 9.3.5.3), applies to process step 4.<br>• Absorption of all "primary design boundary objects", all "primary general boundary objects", a few "secondary design boundary objects", and some |

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| | | | | | "tertiary design boundary objects" (e.g. software tools) (Figure 7.8).<br>• Interpersonal verification/confirmation of all primary design and general boundary objects, and some secondary and tertiary design boundary objects (Figure 7.8). |
| Secondary General Boundary Objects | Intervention Content and App Design Feature Objects | CA | LA | CL | • "Intervention content and app design feature objects" replaces "secondary general boundary objects".<br>• Addition of "theories" (Section 9.3.5.4), applies mostly to process steps 3, 4 and 5.<br>• Interpersonal verification/confirmation of "theories" (Chapter 3, Section 3.5.1, Table 3.3, and Chapter 4, Figure 4.5) and determinants and correlates (Chapter 3, Figures 3.4, 3.5).<br>• Addition of "behaviour change techniques" (Table 9.9), applies mostly to steps 3, 4 and 5.<br>• Interpersonal verification/confirmation of "behaviour change techniques" (Chapter 3, Section 3.5.3, Table 3.4, and Chapter 4, Box 4.4).<br>• Addition of "persuasive systems design principles" (Section 9.3.5.4), applies mostly to process steps 3, 4 and 5.<br>• Interpersonal verification/confirmation of "persuasive system design principles (Chapter 4, Section 4.4.2, Box 4.5 and Table 4.1).<br>• Addition of "gamification principles" (Table 9.10), applies mostly to process steps 3, 4 and 5.<br>• Interpersonal verification/confirmation of "gamification" (Chapter 4, Section 4.4.2).<br>• Absorption of some "secondary general boundary objects" (e.g. taxonomies) and some "other supporting artefacts and materials" (e.g. physical activity framework) (Figure 7.8).<br>• Interpersonal verification/confirmation of some secondary boundary objects and other supporting artefacts (Figure 7.8). |
| Tertiary Design Boundary Objects | Deployment, Evaluation and Study Objects | CA | LA | CL | • "Deployment, evaluation and study objects" replaces "tertiary design boundary objects".<br>• Addition of "implementation objects" (Section 9.3.5.5), applies to process steps 6 and 7.<br>• Addition of "evaluation objects" (Section 9.3.5.5), applies to process steps 5 and 6.<br>• Addition of "study objects" (Section 9.3.5.5), applies to process steps 5 and 6.<br>• Interpersonal verification/confirmation of some "supporting artefacts" (e.g. RE-AIM) (Figure 7.8). |
| Tertiary General Boundary Objects | Market Surveillance and Continuous Improvement Objects | CA | LA | CL | • "Market surveillance and continuous improvement objects" replaces "tertiary general boundary objects".<br>• Addition of "data tracking and data analytics tools and software" (Section 9.3.5.6), applies to process step 8.<br>• Interpersonal verification/confirmation of some tertiary design boundary objects (Figure 7.8). |
| Supporting Methods | Supporting Methods | CA | LA | CL | • Addition of "project process supporting methods" (Section 9.3.5.7), applies to all process steps.<br>• Addition of "interdisciplinary collaborating team supporting methods" (Section 9.3.5.7), applies to all process steps. |

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| | | | | | • Addition of "activity supporting methods" (Section 9.3.5.7), applies to all process steps.<br>• Absorption of "supporting methods" (Figure 7.8).<br>• Interpersonal verification/confirmation of supporting methods (Figure 7.8). |
| Supporting Guidelines, Standards and Codes of Practice | Standards and Guidelines | CA | LA | CL | • Removal of "codes of practice" term.<br>• Addition of "standards and guidelines" (Section 9.3.5.8), applies to process steps 3 to 8.<br>• Absorption of "supporting guidelines, standards and codes of practice" (Figure 7.8).<br>• Interpersonal verification/confirmation of all supporting standards and guidelines (e.g. WHO physical activity guidelines) (Figure 7.8). |
| Other Supporting Artefacts and Materials | Supporting Artefacts and Materials | CA | LA | CL | • Removal of the word "other".<br>• Addition of "supporting artefacts" (Section 9.3.5.9), applies to all process steps.<br>• Addition of "supporting materials" (Section 9.3.5.9), applies to all process steps.<br>• Absorption of "other supporting artefacts and materials" (Figure 7.8).<br>• Interpersonal verification/confirmation of "other supporting artefacts and materials" (Figure 7.8). |
| **Lessons Learned and New Additions** | | | | | |
| - | Categorisation of Boundary Objects and Supporting Artefacts | CA | LA | CL | • Lessons learned that researchers/academics and industry/commercial practitioners prefer to refer to boundary objects and supporting artefacts in terms of the interdisciplinary collaborative process steps, rather than the primary, secondary and tertiary categories, and the design and general types. |
| - | Real World Examples of Boundary Objects and Supporting Artefacts | CA | LA | CL | • Lessons learned that researchers/academics and industry/commercial practitioners prefer to name boundary objects and supporting artefacts as real world examples rather than refer to them in abstract form.<br>• For example, naming the software and tools used during various steps (e.g. Table 9.5, Table 9.6, Table 9.7 and Table 9.8). |

Based on the construction, language and clarity (layout design) revisions, Figure 10.6 provides an enhanced diagrammatical illustration of the Interdisciplinary mHealth App Design Framework's third main *"boundary objects and supporting artefacts"* component (updated from Figure 9.7 with minor linguistic modifications), which now sufficiently meets all three evaluation criteria.

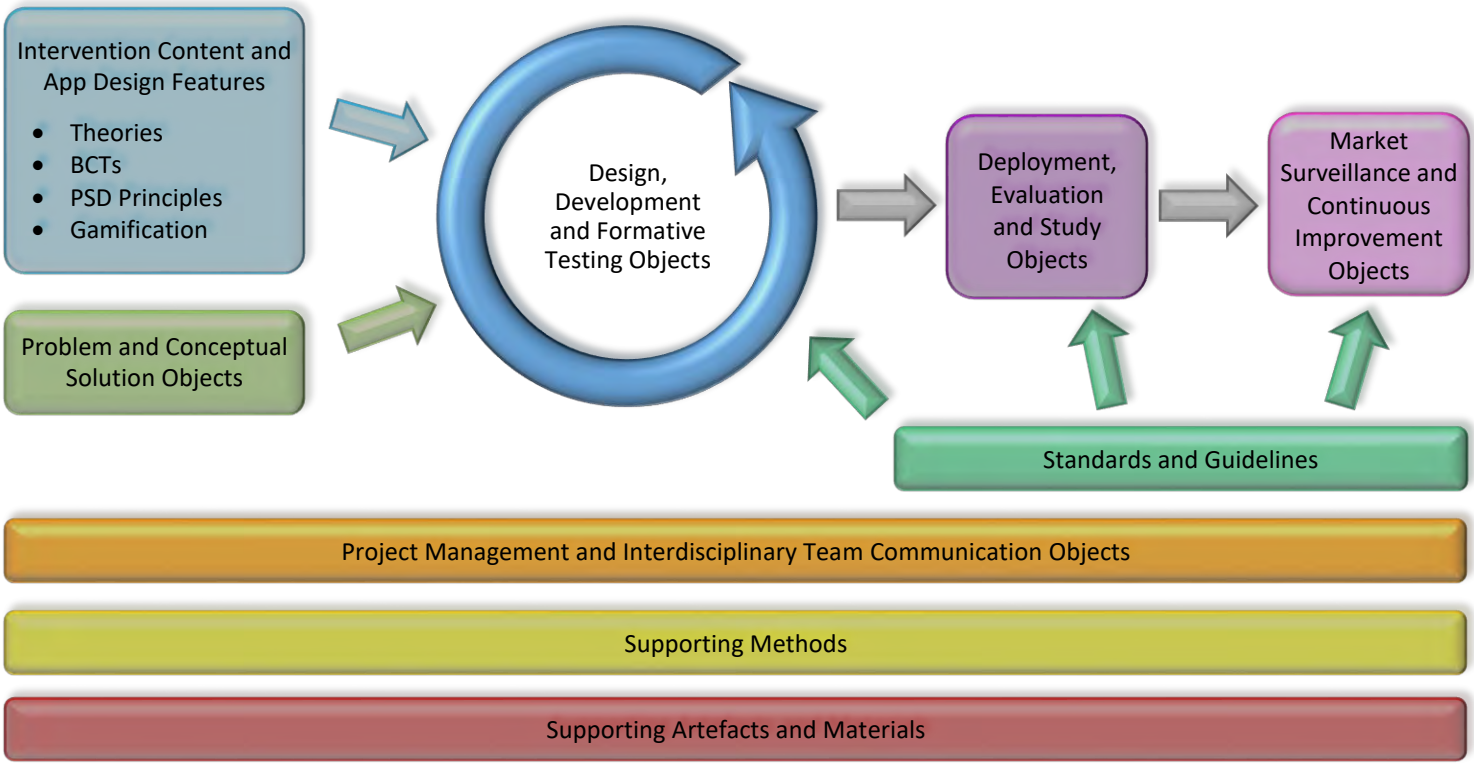



*Figure 10. 6: Enhanced "Boundary Objects and Supporting Artefacts": Main Component 3 of the Revised Framework [Source: Researcher's own construction]*

### 10.3.4 Revisions to Main Component 4: Knowledge

Overall, the framework's fourth main component, *"knowledge"*, required minor to no revisions, with the exception of one major revision. The initial proposed framework's *"knowledge"* component was largely accurate in terms of construction adequacy and language adequacy. Some minor revisions were made in terms of clarity as well as the addition of some new elements and information to the knowledge properties, knowledge boundaries, communication processes, boundary aims, knowledge brokers, shared understanding and knowledge artefacts. The main addition was a *"team culture and dynamics"* subcomponent, which necessitated a moderate language adequacy modification and a major clarity revision to the initial proposed framework's *"knowledge"* component. While the importance of team culture and dynamics was recognised in the initial proposed conceptual framework (Section 7.3.2.1, Appendices J.2 and J.3), it was predominantly discussed as part of the *"actors"* component and was neither incorporated nor emphasised as fundamental to underpinning and supporting knowledge sharing and building practices. Lastly, a lesson learned was that there remains an ongoing need for more and better solutions to addressing and overcoming knowledge related challenges in interdisciplinary mHealth (physical activity) behaviour change intervention app projects. Table 10.5 provides an overview of the revisions to the *"knowledge"* component (and its subcomponents).

*Table 10. 5: Evaluation Criteria Assessment and Revisions to the Framework's Main Component 4: Knowledge [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| Nature and Perspective of Knowledge in Framework | Nature and Perspective of Knowledge in Framework | CA | LA | CL | • Pragmatic perspective of knowledge entangled in practice, actors, process and objects/artefacts interpersonally verified/confirmed.<br>• Interpersonal verification/confirmation of the importance and challenges of making tacit knowledge and perspectives explicit.<br>• Importance of collaborative knowledge sharing and building interpersonally verified/confirmed. |
| Knowledge Properties | Knowledge Properties | CA | LA | CL | • Value/richness and challenges of differences in interdisciplinary collaborating team members' diverse backgrounds (communities of practice) and perspectives interpersonally verified.<br>• Contrasting differences between health and technology fields interpersonally verified (Chapter 4, Sections 4.4.1 and 4.4.3.1, Box 4.1, Figure 4.6 and Figure 4.7).<br>• Dependencies between interdisciplinary team members' heteropraxial activities verified.<br>• Arising novelties in the interdisciplinary collaborating team and the mHealth physical activity intervention app field verified.<br>• Addition of key differences between academia/ research and industry/commercial practice.<br>• General presence of differences, dependencies and novelties interpersonally verified. |
| Knowledge Boundaries | Knowledge Boundaries | CA | LA | CL | *Syntactic*<br>• Language and jargon differences between interdisciplinary team members verified.<br>• Addition of language differences between interdisciplinary team and end users.<br>• Addition of language differences between interdisciplinary team and external stakeholders<br>• Addition of language differences between academia/research and industry.<br>*Semantic*<br>• Interpretation of meaning differences verified.<br>• Interpretive flexibility of terminology verified.<br>• Assumptions of interpretation of meaning taken for granted verified.<br>• Addition of preference differences for methods and approaches between health and technology.<br>• Addition of differences in operationalisation of BCTs, PSD and gamification principles.<br>*Pragmatic*<br>• Differences in interests, values and goals between interdisciplinary collaborating team members verified.<br>• Addition of key differences in interests, values and goals between academia and industry. |

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| | | | | | • Addition of differences in interests between project leaders and general team members.<br>• Resistance to trade-offs and perceived power and political status "at stake" verified.<br>• Addition of differences in "mental models" and "ways of looking at and approaching problems and solutions" between team members.<br>• Addition of access rights/restrictions issues.<br>• Addition of differences in expectations between team members (assumptions taken for granted). |
| Knowledge Communication Processes | Knowledge Communication Processes | CA | LA | CL | *Exchange*<br>• Importance of continuous communication exchange and information processing verified.<br>*Deliberation*<br>• Importance of continuous communication deliberations verified.<br>*Negotiation*<br>• Importance of balancing power/political status and power dynamics verified.<br>• Open channels of negotiation verified.<br>• Addition of managing and negotiating expectations, both within interdisciplinary team and between academia and industry<br>• Addition of using explicit justifications to motivate particular perspectives and interests. |
| Knowledge Boundary Aims | Knowledge Boundary Aims | CA | LA | CL | *Common language*<br>• Need for common language throughout process and mHealth app project lifespan verified.<br>• Addition of importance of and value in using simple, plain, lay language with no jargon.<br>*Common meanings*<br>• Need for common meanings throughout process and mHealth app project lifespan verified.<br>*Common interests*<br>• Need for common interests, values and goals throughout process and mHealth app project lifespan verified.<br>• Importance of shared aims and goals verified.<br>• Importance of shared (product) vision verified.<br>• Addition of importance of shared team purpose. |
| Knowledge Brokers | Knowledge Brokers | CA | LA | CL | *Knowledge broker (role)*<br>• Interpersonal verification of role as neutral, objective, liaison, translator; speaks some language of all communities; weakly linked to several communities yet full members of none.<br>• Interpersonal verification of role as primarily bridging health and technology divide (Chapter 7, Section 7.6.2.2 and Figure 7.11).<br>• Interpersonal verification of role as assumed by project leader, manager or team leader (Figure 9.4).<br>*Knowledge brokering (responsibilities/activities)*<br>• Interpersonal verification of responsibilities for: guiding and managing interdisciplinary collaborative process; developing shared understanding within interdisciplinary team; managing communication, collaboration and shared understandings towards |

| | | | | | |
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| | | | | | common goal (shared project and product vision); and fostering good team culture and dynamics from an early stage of (and throughout) project. |
| Shared Understanding | Shared Understanding | CA | LA | CL | • Verification of importance of ongoing communication and collaboration in developing a foundational/base shared understanding as key to mHealth app project success, and needs to be developed early on in the project/process.<br>• Verification of importance of shared understanding throughout process and project.<br>• Verification of knowledge sharing, generation and integration practices, using shared mental models and common ground understandings.<br>• Addition of importance of asking questions.<br>• Addition of importance of creating a learning environment.<br>• Verification of knowledge broker as primarily responsible for developing shared understanding, and all team members being responsible for maintaining and continuously improving shared understanding(s).<br>• Absorption of "co-created boundary objects (knowledge artefacts)" (Figure 7.10). |
| Role of Boundary Objects (Knowledge Artefacts) | Role of Boundary Objects (Knowledge Artefacts) | CA | LA | CL | *Syntactic*<br>• Verification of syntactic objects (e.g. glossaries, terms and abbreviations).<br>• Absorption "syntactic boundary objects (knowledge artefacts)" (Figure 7.10).<br>*Semantic*<br>• Verification of semantic objects (e.g. methods, frameworks, models, taxonomies, checklists, software tools such as Jira, PBworks, wikis)<br>• Absorption of "semantic boundary objects (knowledge artefacts)" (Figure 7.10).<br>*Pragmatic*<br>• Verification of pragmatic objects (e.g. graphical diagrams, prototypes, demonstrations)<br>• Absorption of "pragmatic boundary objects (knowledge artefacts)" (Figure 7.10).<br>• Addition of importance and use of documentation throughout project, applies to all process steps – operates at all three boundaries.<br>• Addition of documenting decisions and meeting minutes throughout project lifespan.<br>• Verification of importance of developing clear project and team plans at an early stage of project. Developed in process step 1, but used and referenced during all process steps. |
| **Lessons Learned and New Additions** | | | | | |
| - | Need for More and Better Knowledge Boundary Solutions | CA | LA | CL | • Lessons learned that knowledge challenges remain largely persistence and unresolved in the emerging and evolving interdisciplinary mHealth (physical activity) behaviour change intervention app arena. |

| | | | | | |
|---|---|---|---|---|---|
| - | Team Culture and Dynamics | CA | LA | CL | • Addition of importance of *"team culture and dynamics"* to *"knowledge"* component as the underpinning and root foundation for developing shared understanding and overcoming knowledge boundaries.<br>• Initial proposed framework recognised importance of team culture and dynamics (Section 7.3.2.1, Appendices J.2 and J.3), but did not integrate these elements in the *"knowledge"* component. Revision modifies hierarchical decomposition, elemental and informational arrangement and interrelation of *"knowledge"* subcomponents. |

Based on the construction, language and clarity (layout design) revisions, Figure 10.7 provides an enhanced diagrammatical illustration of the Interdisciplinary mHealth App Design Framework's fourth main *"knowledge"* component (updated from Figure 7.10), which now sufficiently meets all three evaluation criteria. The one major revision was the addition of the "team culture and dynamics" sub-component (with elements drawn from the interview study findings), which provides an underpinning root base for the development of shared understanding, and the sharing, building and overcoming of knowledge boundaries. Graphically, the *"team culture and dynamics"* root base spans longer than and is thicker than the *"shared understanding"* foundation and the *"knowledge boundaries and knowledge processes"*. In addition, based on the revisions to the framework's main *"knowledge"* and *"actors"* components, Figure 10.8 (updated from Figure 7.11) provides a revised modification of the nature and role of knowledge betwixt several heterogeneous communities of practice, thereby representing multiple knowledge properties, knowledge boundaries and knowledge processes between all interdisciplinary collaborating team members.

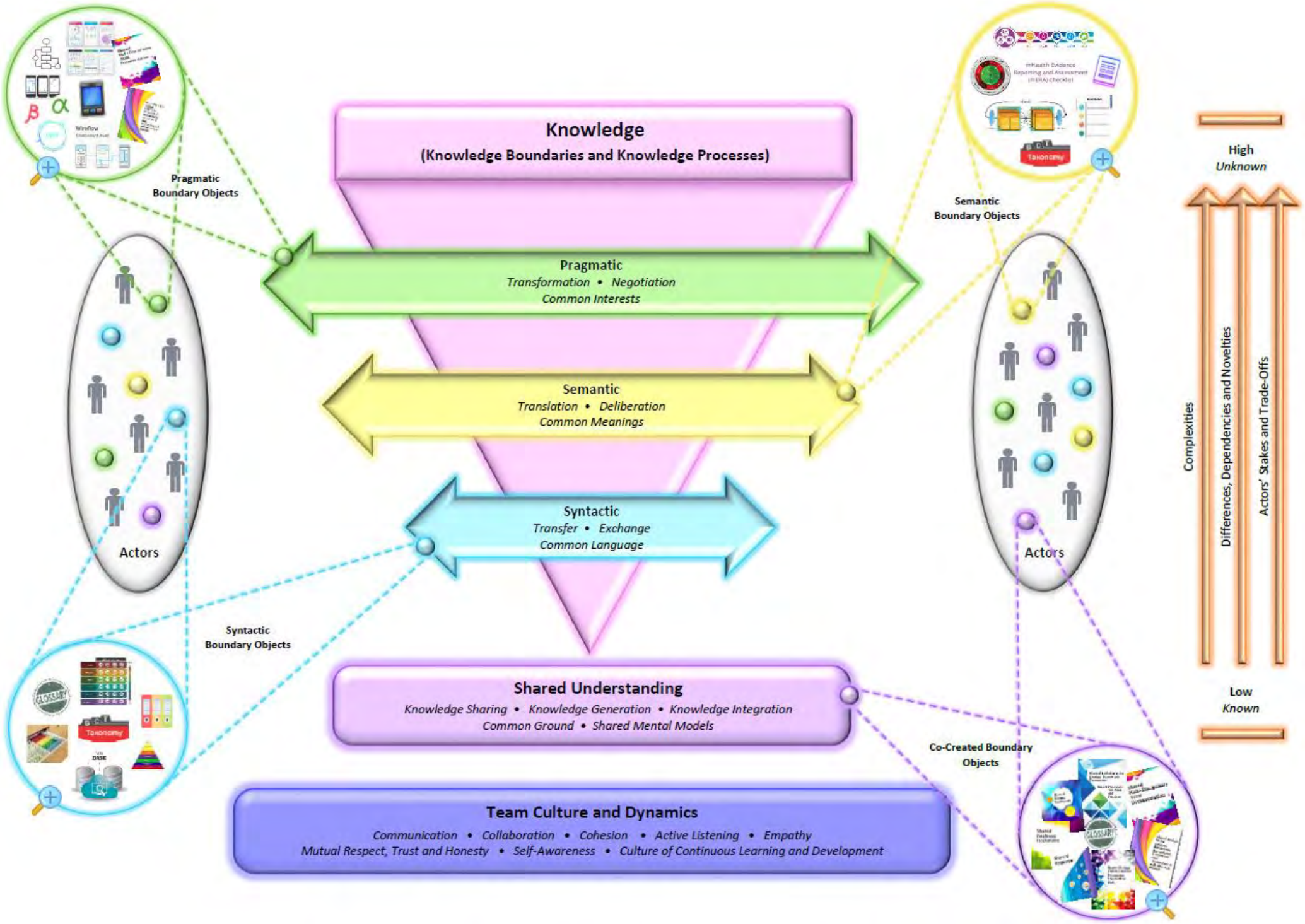



*Figure 10. 7: Enhanced "Knowledge": Main Component 4 of the Revised Framework [Source: Researcher's own construction]*

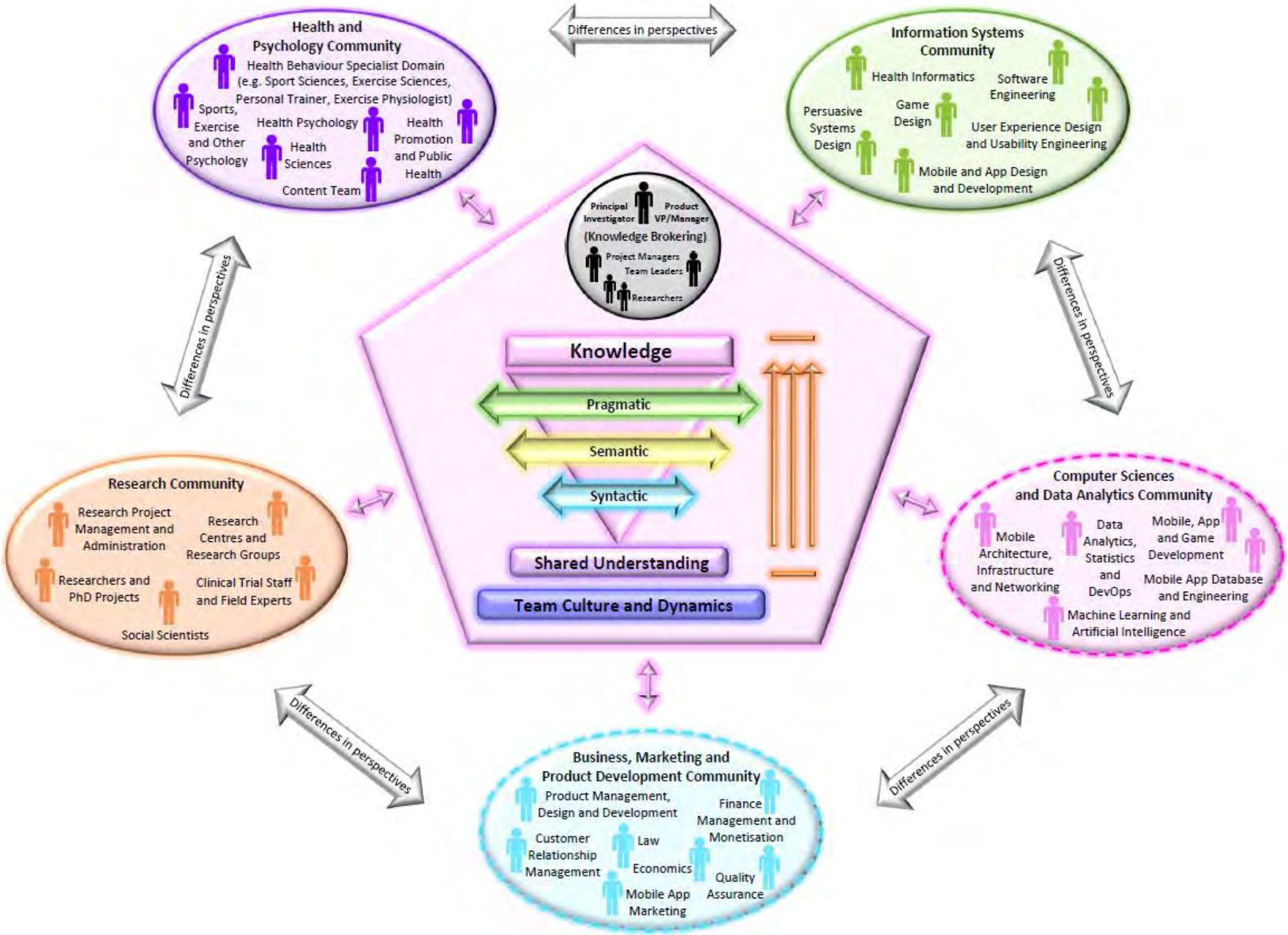



*Figure 10. 8: Enhanced "Knowledge": Multiple Knowledge Properties Boundaries and Processes (Revised Framework) [Source: Researcher's own construction]*

### 10.3.5 Revisions to Supplementary Component 1: Project Boundary

Overall, the framework's first supplementary component, *"project boundary"*, required only a few minor revisions. The initial *"project boundary"* component was largely accurate in terms of construction adequacy in reflecting real world practice, apart from the addition of a lesson learned that a few projects sometimes scope their product and physical activity behaviour change interventions for multi-platform delivery (such as mobile apps and websites). Furthermore, the initial proposed *"project boundary"* component was largely accurate in terms of language adequacy and clarity, despite there being a minor revision of terminology and the addition of a three-category scale for whether mHealth physical activity behaviour change intervention app projects operate on international, national or local levels. Table 10.6 provides an overview of the revisions to the *"project boundary"* component.

*Table 10. 6: Evaluation Criteria Assessment and Revisions to the Framework's Supplementary Component 1: Project Boundary [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| Project Boundary Structure | Project Boundary Structure | CA | LA | CL | • Interpersonal verification of project boundary as flexible, blurry and permeable. Surrounding contextual, cultural, historical and socio-environmental factors can affect and influence project (e.g. COVID-19, advancing mobile app digital technology).<br>• Interpersonal verification of project boundary as providing sufficient structure and scope for team to achieve project goals and objectives. |
| Project Boundary Space | Project Boundary Space | CA | LA | CL | • Interpersonal verification of project goals and objectives being defined within project boundary space.<br>• Interpersonal verification of project boundary as containing shared problem and solution space, with communication and collaboration activities functioning inside the project boundary.<br>• Interpersonal verification of project boundary as environment where team culture and dynamics are established and developed. |
| Project Boundary Scope and Context | Project Boundary Scope, Scale and Context | CA | LA | CL | • Addition of "scale" term.<br>• Interpersonal verification of importance of defining a clear project scope and context at an early stage of project inception.<br>• Addition of three main project size scales: international, national, and local. |

| Lessons Learned and New Additions | | | | | |
|---|---|---|---|---|---|
| - | Project Boundary Digital Scope | CA | LA | CL | • Lesson learned that some mHealth physical activity intervention projects are scoped to create products for both mobile devices (apps) and websites.<br>• Lesson learned that project goals and objectives are sometimes scoped to deliver the same product and physical activity behaviour change intervention to more than one digital technology platform. |

Based on the construction, language and clarity (layout design) revisions, Figure 10.9 provides an enhanced diagrammatical illustration of the Interdisciplinary mHealth App Design Framework's first supplementary *"project boundary"* component, which now sufficiently meets all three evaluation criteria. Figure 10.9 (updated from Figure 7.12) incorporates the revisions to the framework's main *"actors"*, *"knowledge"*, *"process"* and *"boundary objects and supporting artefacts"* components, of which the revisions to the latter two are recognisable.

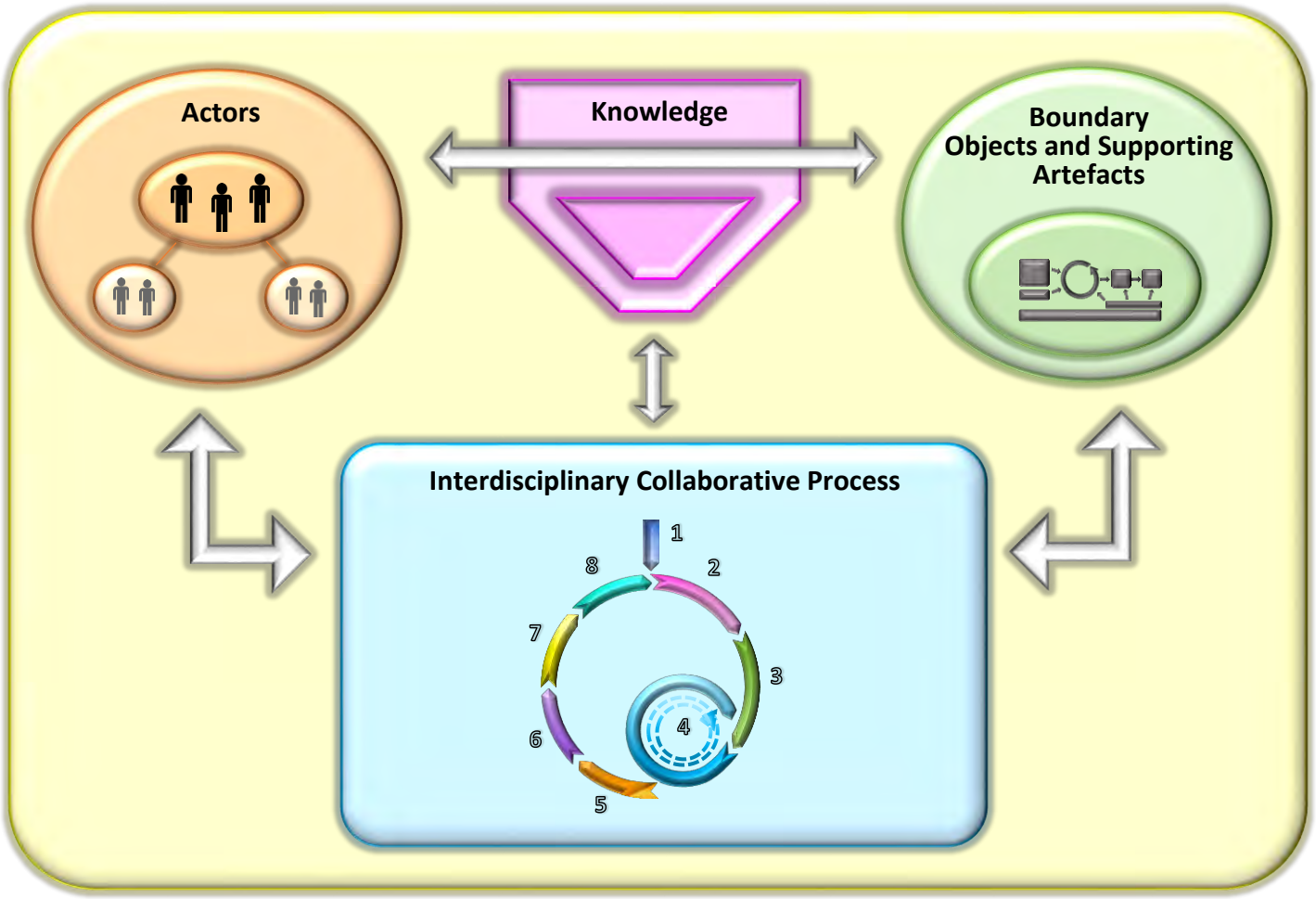



*Figure 10.9: Enhanced "Project Boundary": Supplementary Component 1 of the Revised Framework [Source: Researcher's own construction]*

### 10.3.6 Revisions to Supplementary Component 2: Outcomes

Overall, the framework's second supplementary component, *"outcomes"*, required one major revision to the *"product outcome"* subcomponent. The initial *"outcomes"* supplementary component, and the relationship between its constituting subcomponents, was accurate in terms of construction adequacy in reflecting real world practice. The major revision involved the addition of *"goals and objectives"* to the *"product outcome"* subcomponent, informed by the interview study findings, which necessitated a moderate language adequacy modification and a major clarity revision to the initial proposed framework's *"product outcome"* subcomponent. While the importance of goals and objectives were recognised in the initial proposed conceptual framework (Section 7.2.1 and 7.7.1), it was not integrated with the *"outcomes"* component. Table 10.7 provides an overview of the revisions to the *"outcomes"* component.

*Table 10.7: Evaluation Criteria Assessment and Revisions to the Framework's Supplementary Component 2: Outcomes [Source: Researcher's own construction]*

| Proposed Framework (Chapter 7) | Revised FW based on Evaluation Study Findings (Chapter 9) | Framework Evaluation Criteria | | | Enhanced Framework Revisions |
|---|---|---|---|---|---|
| | | CA | LA | CL | |
| Process Outcome | Process Outcome |  |  |  | • Interpersonal verification of the importance of providing an interdisciplinary collaborating team with a clear and planned object-supported and knowledge-integrated interdisciplinary collaborative process.<br>• Interpersonal verification of the importance of an interdisciplinary collaborative process requiring a high performing interdisciplinary collaborative team with good team culture and dynamics (aligning with Appendix J.3 and the new *"knowledge"* subcomponent). |
| Product Outcome | Product Outcome |  |  |  | • Addition of *"goals and objectives"* to *"product outcome"* subcomponent.<br>• Addition of "the health goal", "the project goal and objective" and "the interdisciplinary collaborative team objective" elements (Figure 9.2).<br>• Interpersonal verification of product as final mHealth physical activity behaviour change intervention app project output (outside of product boundary and released into real world for consumer (end user) use).<br>• Interpersonal verification of mHealth app product as an output of iterative crystallised object-supported and knowledge-integrated process steps and activities performed by interdisciplinary collaborating team. |

| | | | | | |
|---|---|---|---|---|---|
| Process-Product Relationship | Process-Product Relationship | CA | LA | CL | • Interpersonal verification of direct and indirect relationship between the *"process outcome"* and *"product outcome"* subcomponents as crucial to mHealth project and physical activity intervention app product success.<br>• Interdisciplinary verification of iteration cycles between *"process outcome"* and *"product outcome"*. |
| **Lessons Learned and New Additions** | | | | | |
| - | Goals and Objectives | CA | LA | CL | • Addition of *"goals and objectives"* to *"product outcome"* subcomponent.<br>• The initial proposed framework recognised the importance of well-defined goals and objectives, but did not integrate these elements into the *"outcomes"* component. Revision modifies hierarchical decomposition, elemental and informational arrangement and interrelation of the *"product outcome"* subcomponents. |

Based on the construction, language and clarity (layout design) revisions, Figure 10.10 provides an enhanced diagrammatical illustration of the Interdisciplinary mHealth App Design Framework's second supplementary *"outcomes"* component, which now sufficiently meets all three evaluation criteria. Figure 10.10 (updated from Figure 7.13) integrates the new addition of *"goals and objectives"* (Figure 9.2) to the *"product outcome"* subcomponent.

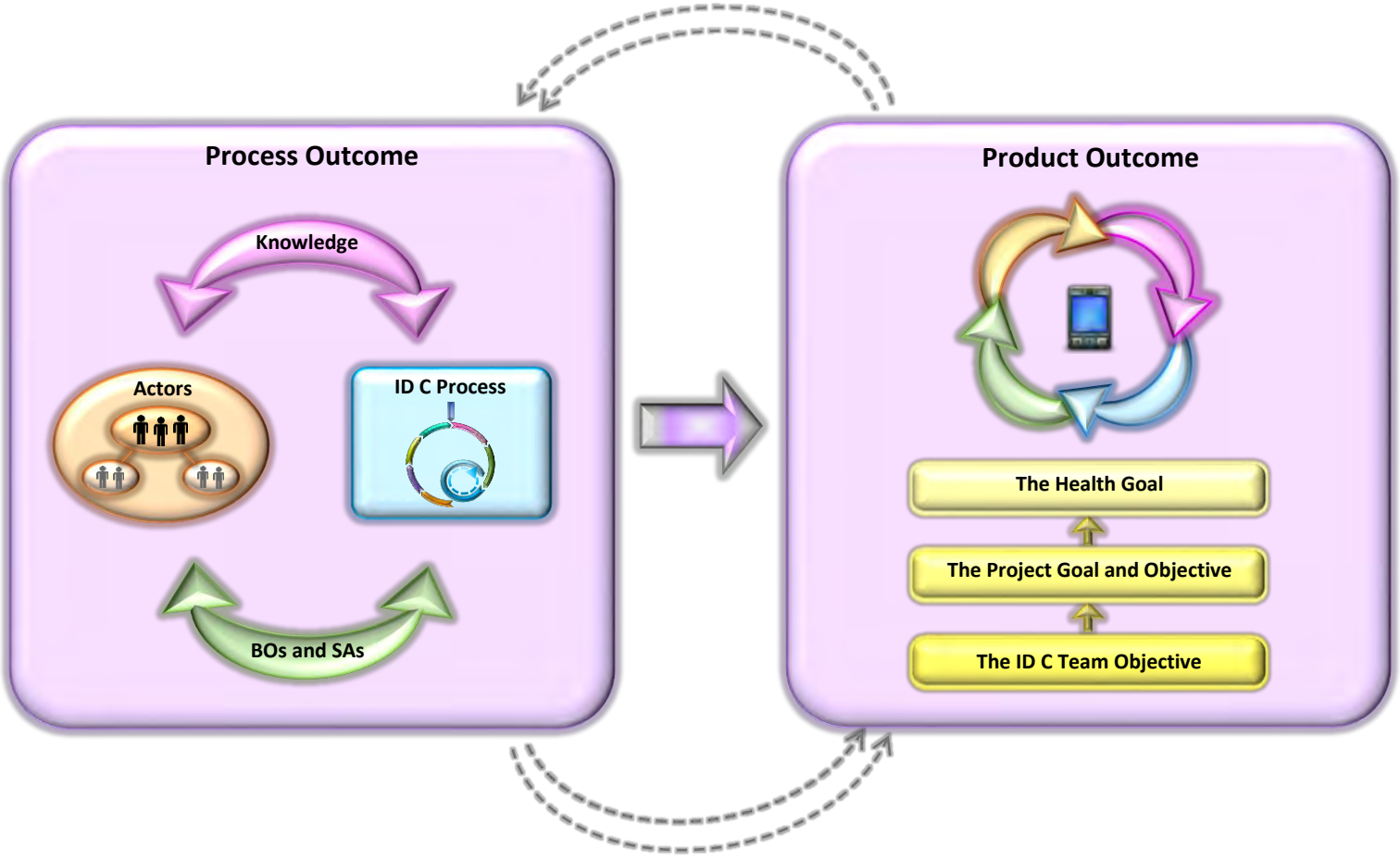



*Figure 10.10: Enhanced "Outcomes": Supplementary Component 2 of the Revised Framework [Initialisms: ID – Interdisciplinary; C – Collaborative; BOs – Boundary Objects; SAs – Supporting Artefacts] [Source: Researcher's own construction]*

## 10.4 The Overall Structure of the Enhanced Interdisciplinary mHealth App Design Framework

After the various minor, moderate and major revisions were made to the four main and two supplementary components, the overall structure of the enhanced Interdisciplinary mHealth App Design Framework required two major revisions. Firstly, the framework's second main *"interdisciplinary collaborative process"* component received major modifications to the main steps and overall diagrammatic representation of the process. Secondly, the framework's third main *"boundary objects and supporting artefacts"* component received a major revision from distinguishing between three categories and two types of boundary objects and three types of supporting artefacts, to rather distinguishing between objects and artefacts in terms of process steps. These two major revisions were mainly in terms of clarity, specifically the decomposition and elemental and informational arrangement of the framework's subcomponents.

In addition to the revisions and interpersonal verifications of the framework's main and supplementary components, the interview study findings also verified the complex and intricately interwoven pragmatic sociomaterial and symbolic interactionist entanglement, and multi-reciprocal, interdependent and interrelated relationships between the framework's components (and subcomponents), and their conjoint and synergistic influence on achieving the shared common aims of mHealth (physical activity) intervention app projects. After having made the overall structure revisions, the enhanced Interdisciplinary mHealth App Design Framework now sufficiently meets all three of the evaluation criteria for construction adequacy, language adequacy and clarity. Figure 10.11 provides a diagrammatical illustration of the enhanced Interdisciplinary mHealth App Design Framework (a revision and modification of Figure 7.2).

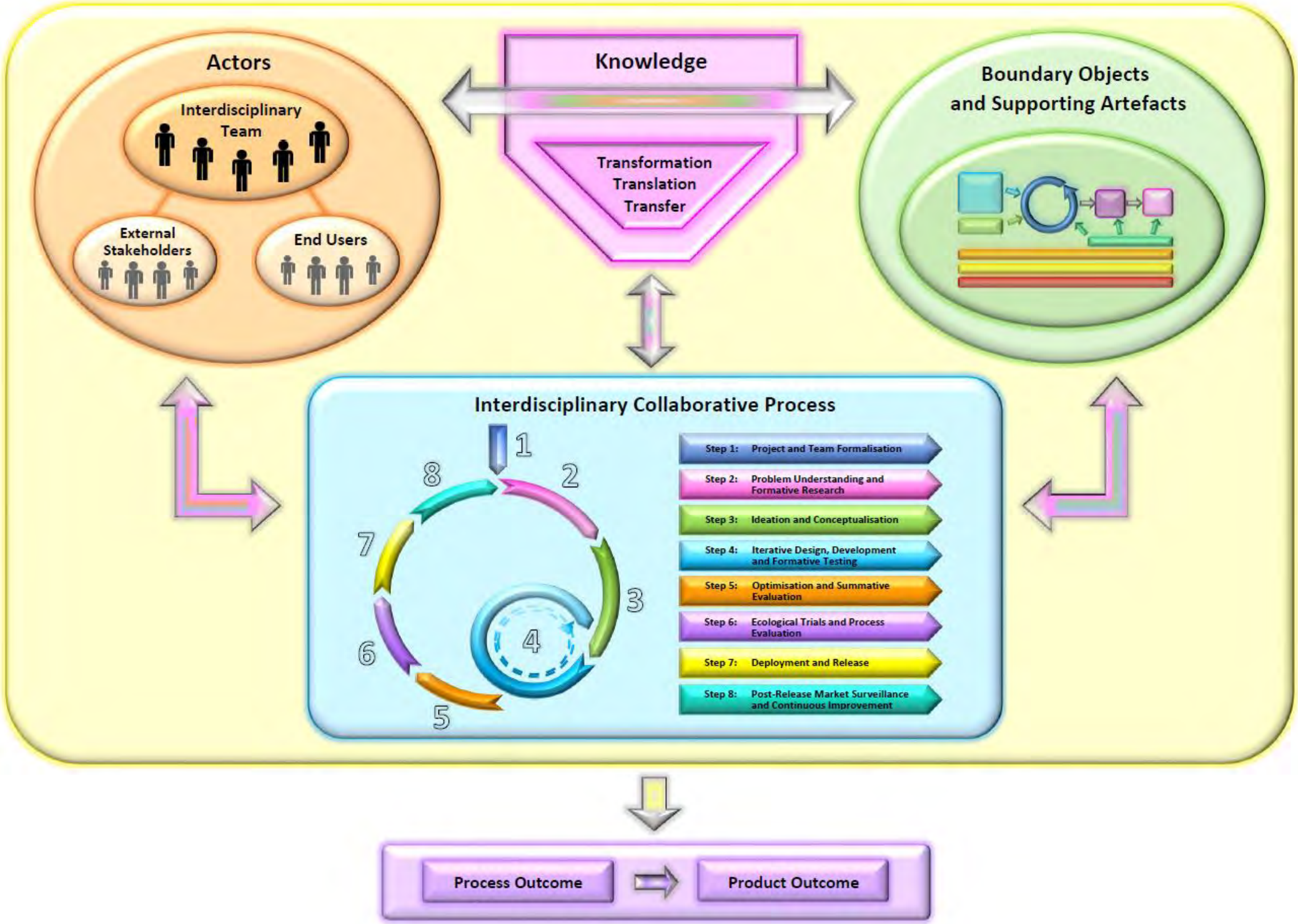



*Figure 10.11: Overall Structure of Enhanced (Revised) Interdisciplinary mHealth App Design Framework [Source: Researcher's own construction]*

## 10.5 Applying the Enhanced Interdisciplinary mHealth App Design Framework: Guideline Recommendations and Boundary Objects

The Interdisciplinary mHealth App Design Framework includes the provision of guideline recommendations for applying each of the four main components, and proposes several boundary objects that interdisciplinary collaborating teams can employ, reference and adapt for use in their particular mHealth physical activity behaviour change intervention app project contexts. As explicitly stated and justified in the evaluation methodology (Chapter 8, Section 8.4.5), the evaluation study's interview questions were specifically designed to ask participants questions that verified and confirmed the framework's components and subcomponents on a middle-to-high level of abstraction, rather than a granular low-level. For this reason, the construction adequacy, language adequacy and clarity of the guideline recommendations and boundary objects were not interpersonally verified directly, but rather indirectly through the various revisions and modifications to the main and supplementary components of the framework. Table 10.8 provides an overview of the guideline recommendations and boundary objects proposed as supplementary framework contributions, including minor and moderate revisions were necessary. As a caveat, the proposed objects only function as boundary objects in real world use if they adhere to the three core property criteria, otherwise they simply function as supporting artefacts that can be borrowed and adapted for use in any given mHealth physical activity behaviour change intervention app project context.

*Table 10.8: Enhanced Framework Revised Guideline Recommendations for Application and Boundary Object Supplementary Contributions [Source: Researcher's own construction]*

| **Framework Component** | **Boundary Objects** *(if three core properties are met in practice)* | **Guideline Recommendations for Application** |
|---|---|---|
| **Actors** | *Actors Diagram*<br>• Graphically illustrates interdisciplinary collaborating team, external stakeholders and end users<br>• Figure 10.2, Figure 10.3 and Figure 10.4<br>*Actors Template*<br>• Details descriptions of interdisciplinary collaborating team members, external stakeholder or end users<br>• Table 7.2, Appendix J.1 | *Interdisciplinary Collaborating Team Member and Perspectives Template*<br>• Outlines and details each team member's perspectives, approaches/ methods, theories and practices<br>• Appendix J.2<br>*Guideline Recommendations for High-Performing Interdisciplinary Collaborating Teams*<br>• Guidelines for team members to reference, learn from and apply<br>• Appendix J.3 |

| | | |
|---|---|---|
| **Interdisciplinary Collaborative Process** | *Process Diagram*<br>• Graphically illustrates a project's shared interdisciplinary collaborative process steps for team members to reference and negotiate around<br>• Figure 10.5<br>*Process Template*<br>• Outlines details of a project's shared interdisciplinary collaborative process steps and activities for team members to reference and negotiate around<br>• Table 7.3, Appendix K.3 | *Guideline Recommendations for Applying the Framework's Interdisciplinary Collaborative Process*<br>• Guideline recommendations specify how the interdisciplinary collaborative process steps and activities can be applied in real world practice, particularly in terms of flexible use<br>• Section 7.4.4.1 |
| **Boundary Objects and Supporting Artefacts** | *Boundary Objects and Supporting Artefacts Diagram*<br>• Graphically illustrates and identifies the main objects and artefacts teams use at each process steps<br>• Figure 10.6<br>*Boundary Object Core Properties Template (Optional Use)*<br>• Outlines the three core property criteria for objects to be classified as boundary objects; team members can learn from<br>• Table 7.4, Appendix L.2<br>*Boundary Object Characteristics Template (Optional Use)*<br>• Outlines the characteristics of boundary objects; team members can learn from<br>• Table 7.5, Appendix L.3<br>*Boundary Object Nature Qualities Template (Optional Use)*<br>• Outlines boundary objects' nature qualities; team members can learn from<br>• Table 7.6, Appendix L.4 | *Guideline Recommendations for Applying the Framework's Boundary Objects and Supporting Artefacts Component*<br>• Guideline recommendations specify how interdisciplinary collaborating teams can manage, track and record the boundary objects and supporting artefacts they employ, use, create and borrow during the interdisciplinary collaborative process and project lifespan<br>• Section 7.5.4.1, Table 7.7 |
| **Knowledge** | *Knowledge Diagrams*<br>• Graphically illustrates knowledge boundaries, communication processes, and knowledge artefacts, and outlines key differences, dependencies, novelties, stakes and trade-offs<br>• Figure 10.7 and Figure 10.8<br>*Knowledge Artefacts Lists*<br>• Provides examples of boundary objects serving as knowledge artefacts at the syntactic, semantic and pragmatic knowledge boundaries; team members can reference, learn from and try example artefacts to overcome knowledge boundary challenges<br>• Section 7.6.4, Appendix M.1 | *Guideline Recommendations for Applying the Framework's Knowledge Component (Optional Use)*<br>• Guideline recommendations specify how interdisciplinary collaborating teams can better understand, manage and overcome knowledge boundary challenges<br>• Section 7.6.5, Appendix M.2, Appendix J.2, Appendix J.3 |

## 10.6 Conclusion

The Interdisciplinary mHealth App Design Framework has been developed in response to the ongoing paucity of approaches for guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps targeting individuals at the dual intra-interpersonal socioecological levels of health promotion. The framework comprises four main components including *"actors"*, *"the interdisciplinary collaborative process"*, *"boundary objects and supporting artefacts"* and *"knowledge"*, and two supplementary components including the *"project boundary"* and *"outcomes"*, which have been framed by an innovative solution perspective, *viz*., the boundary object view (tri-composite theoretical framework).

This chapter has contributed to answering the fourth research sub-question as well as the main research question by evaluating, modifying and enhancing the quality, trustworthiness and contextualisation of the Interdisciplinary mHealth App Design Framework in terms of construction adequacy, language adequacy and clarity (using a qualitative DSR linguistic interpretivist approach). Based on the findings from the interview evaluation study, the domain ontology of the enhanced framework has been interpersonally verified, revised and improved to better reflect real world practice in both academic/research and industry/commercial environments. In short, the enhanced Interdisciplinary mHealth App Design Framework (DSR artefact contribution) received minor, moderate and major revisions to all six components, and two major revisions were made to its overall structure. To further enhance the framework going forward, future studies can perform demonstration applications of the framework in specific case contexts to inform additional iterative refinements, modifications and generalisations of the framework to the physical activity domain as well as other modifiable health behaviour change domains (such as healthy eating, weight management and sleep) and other digital technology platforms (such as websites).

# Chapter 11

## Conclusion

*You like to change things, don't you?*

*For the better, I hope.*

*– Sydney Pollack, Out of Africa (1985) –*



## 11.1 Introduction

Digital and mobile app technology is revolutionising the fight against the global NCD pandemic and transforming the ways in which health promotion behaviour change interventions targeting modifiable health risk behaviours, such as physical inactivity, are delivered to individuals across the world (Lai, et al., 2017; Blandford, 2019a; 2019b; WHO, 2019; Sellak, 2020; Boulos and Yang, 2021; Chatterjee, et al., 2021; Sucala, et al., 2021). Despite the increasingly recognised powerful potential and capabilities of mHealth behaviour change intervention consumer apps, and the "explosive" growth and popularity of health and fitness apps worldwide (Kim, et al., 2020, p.2), there exist several key design challenges that influence the effectiveness of said apps, presenting a "wicked" intricately interwoven, complex and multidimensional design problem (Hevner and Chatterjee, 2010, p.11). At the root and heart of this design problem lies a paucity of multi- and interdisciplinary collaborative approaches for guiding and supporting the synergistic amalgamation and integration of heterogeneous knowledge, expertise, skills and practices from multiple relevant disciplines, including health science, psychology, information systems, computer science and business (Blandford, et al., 2018; Kowatsch, et al., 2019; Taj, Klein and van Halteren, 2019; Van Gemert-Pijnen, et al., 2018; Walsh and Groarke, 2019; Bendtsen, et al., 2020; Hermsen, et al, 2020). In light of this knowledge gap, this research sought to propose an interdisciplinary framework, which can be utilised as a reference model, for guiding and supporting the practical collaborative design, development and evaluation of mHealth behaviour change intervention consumer apps, particularised to the physical activity context.

The proposed Interdisciplinary mHealth App Design Framework adopts a novel boundary object view to address the problem, which emphasises the use and creation of boundary objects and supporting artefacts by interdisciplinary project teams. These guide and support teams' heteropraxial activities and knowledge sharing practices during the collaborative design, development and evaluation process, resulting in more innovative and effective mHealth (physical activity) behaviour change intervention app product design solutions. The framework was developed using a DSR approach, which necessitated its evaluation and iterative refinement based on its relevance to the application environment (Hevner, 2007). The framework was evaluated using a qualitative DSR linguistic interpretivist approach with semi-structured interviews, which allowed the components (and subcomponents) of the framework to be interpersonally verified with knowledgeable and experienced researchers/academics and industry/commercial practitioners in terms of construction adequacy, language adequacy and

clarity. The findings and lessons learned from the interview evaluation study informed the revision and modification of the enhanced framework to better reflect real world practice, and confirmed its significance as a novel and valuable contribution. The framework received minor, moderate and major revisions to all of its components, and two major revisions to its overall structure. Through continued revisions and enhancements, the framework can be further improved and generalised to suit other digital platform and health behaviour contexts.

This chapter provides a conclusion to this research, which falls within Step 5 ("conclusion") of the study's DSRM, as illustrated in Figure 11.1. In this chapter, the research questions are firstly outlined and answered, after which the theoretical, practical and methodological research contributions are presented. Thereafter, the implications, reflections and limitations of the research are discussed. Recommendations for future research and further enhancements to the framework are then presented, followed by concluding remarks, which concludes the research.

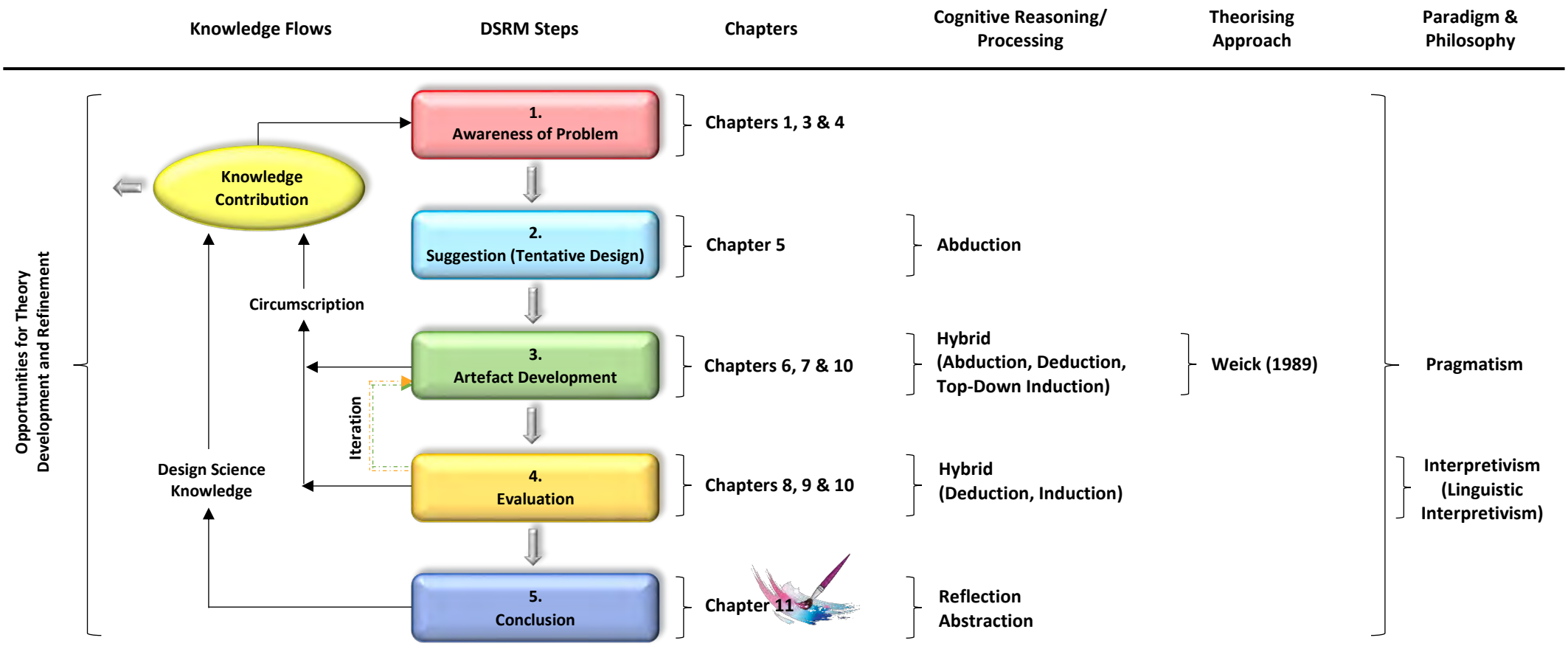



*Figure 11. 1: DSRM: Conclusion of Research [Researcher's own construction, adapted from Vaishnavi and Kuechler (2004; 2008), Kuechler and Vaishnavi (2008), Vaishnavi and Kuechler (2015), and Vaishnavi, Kuechler and Petter (2017)]*

## 11.2 Research Questions and Answers

The study sought to answer the following main research question:

**Main Research Question:**

*How can interdisciplinary teams collaborate in the design, development and evaluation of mHealth physical activity behaviour change intervention apps?*

The main research question has been addressed throughout this research study. The study has resulted in The Interdisciplinary mHealth App Design Framework contribution, which can be applied as a reference model by addressing all of the framework components, including the four main *"actors"*, *"interdisciplinary collaborative process"*, *"boundary objects and supporting artefacts"* and *"knowledge"* components, and the two supplementary *"project boundary"* and *"outcomes"* components. Guidelines recommendations and supplementary boundary object contributions were also provided for applying the framework in real world practice.

The main research question was broken down into the following four research sub-questions, which were incrementally explored and answered at various stages of the DSR process:

**Research Sub-Question 1:**

*What is the role of mobile technology in delivering interventions for promoting physical activity behaviour change?*

The first research sub-question was answered in Chapters 3 and 4. Chapter 3 provided insight into the contextual landscape problem, particularly the global NCD and physical inactivity pandemics. It introduced the importance of and challenges associated with designing and delivering health promotion behaviour change interventions that target modifiable health risk behaviours, such as physical inactivity, at the dual intra-interpersonal socioecological levels. In the first two sections of Chapter 4, the digital health landscape and the consumer health informatics subfield were outlined, which paved the introduction of mHealth app technology as a powerful and increasingly popular platform for delivering physical activity promotion behaviour change interventions to individuals across the world. In these discussions, the strengths, opportunities and capabilities of mHealth physical activity behaviour change intervention consumer apps were also presented.

**Research Sub-Question 2:**

*What are the key challenges regarding the design, development and evaluation of mHealth behaviour change intervention apps for physical activity?*

The second research sub-question was answered in Chapter 4. In the third section of Chapter 4, the taut contestation, and need for collaboration and integration, between the two broad health behavioural sciences and information systems perspectives, and their different approaches to designing, developing and evaluating mHealth (physical activity) behaviour change intervention apps, was presented and discussed. Furthermore, key design challenges were identified and described, which primarily concerned the integration of theory, incorporation of evidence-based BCTs, operationalisation of PSD and gamification principles, and adoption/sustained usage; all of which influence the effectiveness of mHealth (physical activity) behaviour change intervention consumer apps when targeting individuals at the dual intra-interpersonal socioecological levels of health promotion.

It was further explained that in addressing these key challenges, there has been an increase in calls for "holistic" multi- and interdisciplinary approaches that aim to bridge the divide between the two broad perspectives. Furthermore, these approaches incorporate diverse knowledge, expertise and skills from several heterogeneous practice communities, all of which are necessary and relevant to the design and production of effective mHealth (physical activity) behaviour change intervention consumer apps (Van Gemert-Pijnen, et al., 2011, p.1; Wang, et al., 2019, p.1). A preliminary critical review of nine existing multi- and interdisciplinary approaches revealed several key challenges and knowledge gaps, which confirmed the ongoing need for novel solution perspectives to address the lack of guidance and support provided to interdisciplinary collaborating teams for designing, developing and evaluating these mHealth intervention apps.

**Research Sub-Question 3:**

*How can a tri-composite theoretical framework (boundary object view) inform the main components of an interdisciplinary framework for the collaborative design, development and evaluation of mHealth physical activity behaviour change intervention apps?*

The third research sub-question was answered in Chapters 5, 6 and 7. Chapter 5 proposed the tri-composite theoretical framework – comprising community of practice theory, boundary

object theory and knowledge boundary theory – as the novel tentative design solution to address the defined research problem. Concisely referred to as the *"boundary object view"*, the design solution emphasised the use and creation of boundary objects and supporting artefacts by interdisciplinary teams in guiding and supporting their heteropraxial activities and knowledge sharing practices during the collaborative design, development and evaluation process of mHealth (physical activity) behaviour change intervention app projects.

In Chapter 6 the tri-composite theoretical framework was used, in conjunction with Weick's (1989) theorising process and a hybrid cognitive reasoning strategy, to conduct a critical thematic and comparative theoretical analysis on twenty selected existing multi- and interdisciplinary digital health intervention development approaches (categorised into four perspectives) in order to elicit component themes and subthemes necessary and relevant to inform the development of the conceptual framework artefact.

In Chapter 7, the boundary object view component theme and subtheme findings were used to inform the first iteration development of the proposed conceptual Interdisciplinary mHealth App Design Framework. The four main components included the *"actors"*, *"interdisciplinary collaborative process"*, *"boundary objects and supporting artefacts"* and *"knowledge"*, and the two supplementary components included the *"project boundary"* and *"outcomes*".

**Research Sub-Question 4:**

*What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context?*

The fourth research sub-question was answered in Chapters 8, 9 and 10, and specifically concerned the evaluation and iterative refinement and revision of the enhanced framework. In Chapter 8, the research methodology used to evaluate the conceptual framework was presented, namely a qualitative DSR linguistic interpretivist approach with virtual semi-structured interviews as the research instrument and a qualitative thematic analysis (incorporating a hybrid deductive and inductive cognitive strategy) as the data analysis method. The three evaluation criteria, construction adequacy, language adequacy and clarity, were also outlined.

Chapter 9 presented the participants' demographic information and the interview study findings and discussion, which provided rich and valuable contextual insights into the key actor,

process, object and knowledge sharing elements relevant to guiding and supporting the interdisciplinary collaborative design, development and evaluation of mHealth physical activity behaviour change intervention consumer apps.

In Chapter 10, the interview study findings and proposed conceptual framework were compared against the evaluation criteria, and various minor, moderate and major revisions and modifications were made to the four main and two supplementary components, resulting in an enhanced Interdisciplinary mHealth App Design Framework.

## 11.3 Research Contributions

This research contributes to knowledge on theoretical, practical and methodological levels (Gregor and Hevner, 2013; Baskerville, et al., 2018; Hevner, et al., 2018). On a theoretical level, in addition to the newly proposed design artefact, contributions are made to the mHealth intervention app design body of knowledge based on insights resulting from subsets of the research. On a practical level, contributions are made in the form of practical guideline recommendations and real world proof of concept. On a methodological level, contributions are made in terms of DSR construction and evaluation knowledge.

### 11.3.1 Theoretical Contributions

***The Design Artefact***

The primary contribution of this research is the Interdisciplinary mHealth App Design Framework, which constitutes a valid DSR design artefact (Vaishnavi, Kuechler and Petter, 2017; Vom Brocke, Hevner and Maedche, 2020). In terms of Gregor and Hevner's (2013) DSR contribution types (Figure 11.2), the framework represents nascent design theory (at Level 2), which is simultaneously abstract and contextual, and lies mid-way between complete and mature theory (Level 3) and situated instantiations (Level 1).

| | Contribution Types | Example Artefacts |
|---|---|---|
| More abstract, complete and mature knowledge<br>↕ ↕ ↕ ↕<br>More specific, limited and less mature knowledge | Level 3. Well-developed design theory about embedded phenomena. | Design theories (mid-range and grand theories). |
| | Level 2. Nascent design theory – knowledge as operational principles/architecture. | Constructs, methods, models, frameworks, design principles, technological rules. |
| | Level 1. Situated implementation of artefact. | Instantiations (software products or implemented processes) |

*Figure 11. 2: Design Science Research Contribution Types [Adapted from Gregor and Hevner (2013), "frameworks" example artefacts added from Vaishnavi, Kuechler and Petter (2017)]*

In addition, according to Gregor and Hevner (2013), DSR knowledge can be contributed in one of four distinct quadrants, which differentiates work in terms of solution maturity and application domain maturity (Figure 11.3). Considering that this research proposes a novel design solution (boundary object view) to a known problem (the paucity of multi- and interdisciplinary approaches), and draws from and builds on extant design knowledge (the existing twenty selected approaches and extant literature), the knowledge and artefact contribution falls within the *"improvement"* quadrant (highlighted in Figure 11.3) (Gregor and Hevner, 2013, p.346; Vom Brocke, Hevner and Maedche, 2020).

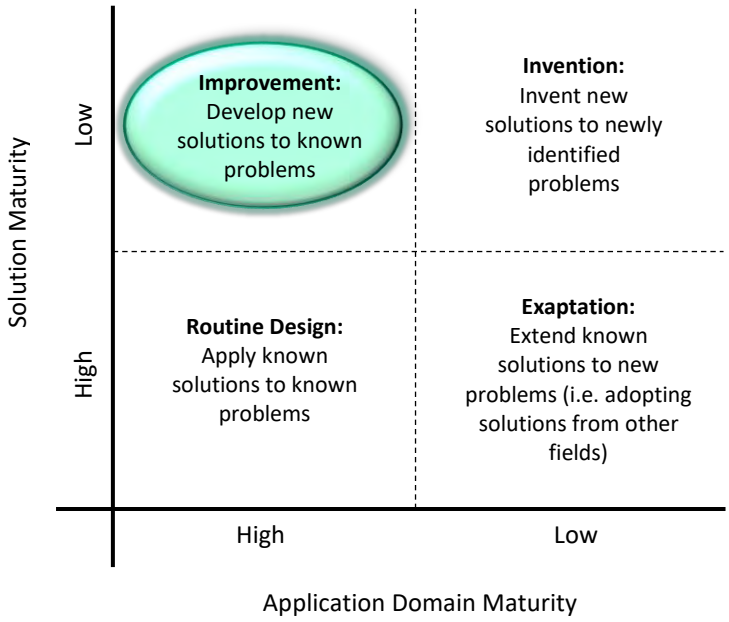



*Figure 11. 3: The DSR Knowledge Contribution Framework*
*[Source: Adapted from Gregor and Hevner (2013)]*

Furthermore, the DSR knowledge contribution of this research (framework) resides at the confluence of the descriptive (Ω) and prescriptive (Λ) knowledge bases, since it draws on knowledge from diverse fields and heterogeneous (product and process) kernel theories, to develop and contribute an interdisciplinary framework that intends to improve real world collaborative mHealth intervention app design, development and evaluation practice (Gregor and Hevner, 2013). Moreover, the design artefact provided theoretical contributions when its components (and subcomponents) were evaluated, interpersonally verified and modified in terms of construction adequacy, language adequacy and clarity. This demonstrated its quality and trustworthiness in reflecting both the application environment's domain ontology, and the real world proof of concept in research/academic and industry/commercial practice.

***Four Contributions to the mHealth Intervention App Design Body of Knowledge***

***(1) Key Strengths, Limitations and Knowledge Gaps of Existing Multi- and Interdisciplinary Digital Health Intervention Development Approaches***

In Chapter 4 (Section 4.4.3, Appendix F), a preliminary critical review of nine existing multi- and interdisciplinary digital health intervention development approaches yielded findings on the key strengths, limitations and knowledge gaps of approaches currently in the knowledge base. Some key challenges and knowledge gaps concern: the structure and nature of current approaches; the use of different methods, frameworks, tools and taxonomies; misunderstandings and miscommunications associated with interpretively flexible terms; the lack of practical guidance for translating and operationalising BCTs and PSD principles into app design features; the composition and functioning of collaborative teams; a lack of toolboxes for teams to select from during the design, development and evaluation process; and the need for better knowledge sharing and shared understanding practices to bridge differences in perspectives and overcome conflicts of interest. The findings contribute to the mHealth intervention app design body of knowledge and can be informative for future studies.

***(2) Key Design Related Challenges of mHealth Physical Activity Behaviour Change Intervention Consumer Apps for Individuals***

In Chapter 4 (Section 4.4.2, Figure 4.4, Appendix D), a critical review of literature on mHealth intervention consumer apps targeting physical activity behaviour change in individuals at the dual intra-interpersonal socioecological levels yielded valuable insights on the design related challenges of said apps. Findings identified common health behaviour change theories, BCTs, PSD and gamification principles, as well as key challenges concerning reporting, translation and operationalisation, interpretive flexibility, acceptance, adoption and sustained usage, as well as effectiveness. A diagrammatic summary of the findings was presented in Figure 4.5, which provides a contribution to the mHealth intervention app design body of knowledge.

***(3) Key Boundary Object View Themes and Subthemes of Existing Multi- and Interdisciplinary Digital Health Development Approaches***

In Chapter 6 (Sections 6.4 and 6.5, Appendix I), a critical review of twenty existing multi- and interdisciplinary digital health intervention development approaches, categorised across Health, Information Systems/Technology, Partnership and Integrative perspectives, yielded

valuable insights regarding the key boundary object view themes and subthemes of the collaborative mHealth intervention app design, development and evaluation space. A template was developed to analyse and compare the twenty selected approaches in terms of: (1) aims and context; (2) actors and community of practice members; (3) perspectives, underlying theories, models tools and existing approaches; (4) process nature, steps and activities; (5) design artefacts, boundary objects and supporting methods; (6) knowledge boundaries; and (7) limitations and lessons learned. The findings of the critical review contributes to the current mHealth intervention app design body of knowledge and can be used to inform future studies.

***(4) Key Challenges and Opportunities for Future Improvement and Research***

In Chapter 9 (Section 9.3.7), six key challenges and opportunities for future improvement and research on the interdisciplinary collaborative design, development and evaluation of mHealth behaviour change intervention apps were identified based on the empirical interview study findings. These findings were classified in terms of: (1) mHealth physical activity app projects; (2) interdisciplinary collaborating teams; (3) the interdisciplinary collaborative process; (4) funding and investments; (5) the divide between academia/research and industry; and (6) current and future advancements in the mHealth physical activity behaviour change intervention app field. These findings contribute to the current body of knowledge and can be useful for informing future studies in the mHealth (physical activity) behaviour change intervention app arena.

## 11.3.2 Practical Contributions

***Guideline Recommendations for Practice***

The Interdisciplinary mHealth App Design Framework artefact contribution was accompanied by practical guideline recommendations for applying the main framework components, as well as several supplementary boundary objects that interdisciplinary collaborating teams can employ, adapt and utilise as common frames of reference to support practice in various mHealth (physical activity) behaviour change intervention app project contexts.

***Practical Proof of Concept***

The main contribution in this research is conceptual and does not include a real world demonstration or application. Davis (2005, p.18), however, argues that “the [practical] contribution may be demonstrated by reasoning, proof of concept, proof of value added, or

proof of acceptance and use". In this research, the researcher demonstrated the practical contribution of the framework in two ways: (1) by reasoning its value as an improvement to existing approaches, and (2) by demonstrating its proof of concept through the interview evaluation study findings and discussion, whereby 31 knowledgeable and experienced researchers/academics and industry/commercial practitioners located across ten international countries interpersonally verified and confirmed the practical relevance of the framework and its six components. As a reference model holding practical proof of concept, various components and elements of the framework can be purposefully employed, adapted and applied practically by teams collaborating in any given mHealth physical activity behaviour change intervention consumer app project context.

### 11.3.3 Methodological Contributions

***DSR Artefact Construction and Evaluation Knowledge***

The Interdisciplinary mHealth App Design Framework was developed and evaluated using the DSRM. The artefact construction process drew on the findings of the critical review on twenty existing approaches [selected through Boell and Cecez-Kecmanovic's (2014) hermeneutic search and acquisition approach], which incorporated the use of Weick's (1989) theorising process and a novel hybrid cognitive reasoning strategy, and also relied on literature findings and the researcher's accumulated knowledge of the interdisciplinary area. The artefact evaluation process involved conducting virtual semi-structured interviews with 31 knowledgeable and experienced researchers/academics and industry/commercial practitioners spanning ten international countries, to interpersonally verify the construction adequacy, language adequacy and clarity of the framework's six components, and to determine the quality, trustworthiness and relevance of the framework to real world practice. The findings from the interview evaluation study were used to inform the iterative revision and modification of the enhanced Interdisciplinary mHealth App Design Framework. Furthermore, the three DSR rigour, design and relevance cycles assisted in developing and evaluating the artefact by ensuring its rigorous grounding in sound knowledge base foundations, its iterative develop/build and justify/evaluate process, and its relevant appropriateness to the real world application domain and environment, respectively (Hevner, 2007).

***DSR Artefact Construction Knowledge***

Two contributions to DSR artefact construction knowledge were made. Firstly, the framework artefact was developed using a tri-composite theoretical framework, which amalgamated three complementary theories (namely community of practice theory, boundary object theory and knowledge boundary theory), and was applied as a novel design solution to a context in which the three theories have not yet been conjointly applied.

Secondly, the framework artefact development process employed a novel hybrid cognitive reasoning strategy, which combined abductive, deductive and top-down inductive reasoning. Abduction allowed the design science researcher to adopt a creative approach to proposing a plausible speculative satisficing solution, which was motivated by their innate "act of insight" (Peirce, 1934, p.181) and guided by their "guessing instinct" (Gold, et al., 2011, p.237). Deduction allowed the researcher to use the tri-composite theoretical framework as a template guide to focus their attention during the critical theoretical analysis, so that themes and subthemes relevant the proposed boundary object view were elicited from existing approaches. Top-down induction allowed the researcher to remain open-minded when analysing the secondary dataset, so that they could induce valuable findings by letting the data "speak to" them (Shepherd and Sutcliffe, 2011, p.368).

***DSR Artefact Evaluation Knowledge***

Two contributions to DSR artefact evaluation knowledge were made. Firstly, a qualitative DSR linguistic interpretivist approach was applied (within an overarching pragmatic paradigm) to the mHealth intervention app design context, in which it had not yet been applied, to evaluate the artefact's quality, trustworthiness and domain ontology through interpersonal verification.

Secondly, the three evaluation criteria (namely construction adequacy, language adequacy and clarity) were drawn from Schüette and Rotthowe's (1998) guidelines of modelling, which propose key principles for assessing, improving and enhancing the quality of information systems conceptual (meta-)models and frameworks. To the best of the researcher's knowledge, these evaluation criteria have not yet been applied within a DSR study, nor have they been used to evaluate and enhance the quality, trustworthiness and contextualisation of a contribution within the interdisciplinary mHealth intervention app design arena.

## 11.4 Implications of the Research

An interdisciplinary approach that leverages the use and creation of boundary objects and supporting artefacts to guide, facilitate and mediate heteropraxial activities and knowledge sharing practices between heterogeneous collaborating communities during the design, development and evaluation project process, contributes valuably to improving the output product solution design and effectiveness potential of mHealth physical activity behaviour change intervention consumer apps. Actors, objects/artefacts, knowledge, processual activities, outcomes and a project boundary are six essential and indispensable components of mHealth intervention app projects. All of these components are complexly and intricately entangled and interdependent in a pragmatic sociomaterial and symbolic interactionist reality. Attempting to design and produce effective mHealth physical activity behaviour change intervention consumer apps without one of these components is impractical and unattainable. For example, attempting to design a physical activity app without using and creating various low-, medium- and high-fidelity prototypes is unworkable. Similarly, attempting to produce a final physical activity app without undergoing several process steps and activities that integrates diverse health, psychology and technological knowledge, is infeasible. Notably though, as a reference model, not all subcomponents and elements of the Interdisciplinary mHealth App Design Framework are mandatory to apply. Researchers and practitioners are permitted to borrow, adapt and apply various aspects of the framework to suit their use within any given mHealth intervention app project context. The key imperative of the framework's utilisation is that all six components be considered given their essential and indispensable entanglement and interdependence.

Furthermore, an interdisciplinary holistic and collaborative approach to mHealth behaviour change intervention app design that considers and incorporates all relevant and necessary perspectives and contributions from several disciplines – including health sciences, psychology, information systems, computer sciences, and business management – is imperative for the ongoing and future success of effective physical activity consumer apps. This is because each discipline offers essential knowledge and practice expertise that is fundamental to the project process and product output. For instance, focusing solely on intervention content and BCTs at the expense of consideration for an app's acceptance, adoption, engagement usability, persuasiveness, and user experience design has shown to result in app ineffectiveness and failure (Liew, et al., 2019; Lee, et al., 2020; Sucala, et al., 2020; Sporrel, et al., 2021). At the same time, focusing purely on creating an app that exclusively

creates for positive, fun and engaging experiences, yet fails to integrate intervention content and BCTs that target determinates/correlates and mechanisms of action, and hence neglects to motivate and empower individuals towards sustainable physical activity behaviour change, also results in app ineffectiveness and failure (Bondaronek, et al., 2018; Baretta, Perski and Steca, 2019; Walsh and Groarke, 2019; Sucala, et al., 2020).

In addition to considering and incorporating the diverse perspectives and contributions of several relevant disciplines, mHealth intervention app projects need to consider and involve end users, either directly or indirectly, in the design, development and evaluation process. Disregarding end users' involvement and feedback in this process has shown to lead to project and product failure, simply because they fall short of meeting consumers' wants and preferences, which results in users abandoning apps for better alternatives that meet their wants and preferences (Verbiest, et al., 2018; Sucala, et al., 2020; 2021).

Moreover, an interdisciplinary holistic and collaborative approach that purposely considers the use and creation of various boundary objects and supporting artefacts during the project design, development and evaluation process has valuable implications for transforming and generating new knowledge, methods, processes and practices in the "young" (Mummah, et al., 2016, p.1) and "emerging" (Arigo, et al., 2019, p.72; Taj, Klein and van Halteren, 2019, p.1) interdisciplinary mHealth intervention app arena. Boundary objects, in particular, demonstrate integral value in serving as common points of reference around which heterogeneous collaborating practice communities can communicate, share knowledge, overcome knowledge boundaries and jointly transform and generate new knowledge, methods, processes and practices. The Interdisciplinary mHealth App Design Framework, and its emphasis on the meaningful and valuable use of boundary objects and supporting artefacts contributes to advancing knowledge and practice in the evolving mHealth intervention app field.

## 11.5 Reflections

Reflections are an important part of a good quality DSR project (as illustrated under the cognitive reasoning/processing activity in Figure 11.1), and should be performed in terms of (1) *the research product*; (2) *the research process and methodology*; and (3) *the researcher's self-reflections and lessons learned from conducting the research* (Vaishnavi and Kuechler, 2008; 2015; Baskerville, et al., 2018).

### 11.5.1 The Research Product

In addition to positioning and summarising the research contributions (outlined in Section 11.3), it is important to reflect more broadly on whether the research has achieved what it originally intended to, and whether the research answers are insightful, useful, usable and valuable. As demonstrated by the answer discussions to the research questions (Section 11.2), the research successfully achieved what it set out to do. For a more general assessment of and reflection on the value of the research product contribution and output, Gregor and Hevner (2013) suggest answering three key questions posed by Hardy, which ask: (1) *"Is it true?"* (2) *"Is it new?"* and (3) *"Is it interesting?"* (Wilson, 2002, p.168).

***Is it true?***

Both the overall DSR methodological research process and the iterative artefact develop-evaluate-revise process (design cycle), from beginning to end, has provided explicit justifications for all decisions made, has exhibited consistent reporting transparency, and has provided substantial evidence for being applied in a credible, dependable, confirmable and trustworthy manner (Lincoln and Guba, 1985; Vom Brocke, et al., 2020). The demonstrated adherence to the DSR guidelines and publication schema further serve to reflect the *truth* of the research product and contributions.

***Is it new?***

This research proposed a novel perspective to a known problem that, prior to this research, had not yet been explored or investigated. Firstly, novelty lies in the development of a tri-composite theoretical framework – which amalgamated three complementary theories, namely community of practice theory, boundary object theory and knowledge boundary theory – to frame an innovative "boundary object view" solution to address the paucity of multi- and interdisciplinary approaches for guiding and supporting the collaborative design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer apps. Secondly, novelty lies in the iterative development and revision of a new Interdisciplinary mHealth App Design Framework (artefact) contribution, which was informed by the novel boundary object view perspective. While novel contributions also lie in the methodological DSR construction and evaluation knowledge and the practical guideline recommendations (outlined in Section 11.3), the boundary object view perspective and framework artefact represent the main *new* contributions of this research.

***Is it interesting?***

While the extent to which this research is interesting is subject to the perspective and interpretation of the reader, several of the interview study participants explicitly described the research as "interesting" in that it presents a novel approach to addressing the defined research problem, and explores an area of research that is notably current with many reported challenges and opportunities. More specifically, the theoretical, practical and methodological research contributions outlined in Section 11.3 comprise elements that could potentially be of interest to researchers and/or industry practitioners. Based on participants' feedback and the research contributions, it is reasonable to argue that this research is *interesting*.

### 11.5.2 The Research Process and Methodology

Upon reflection, the applied DSRM provided a problem-solving approach to addressing a multifaceted and "wicked" real world design problem (Hevner and Chatterjee, 2010, p.11). Furthermore, it allowed for the iterative development, evaluation and revision of an innovative framework artefact contribution that drew from multiple sources (literature, existing multi- and interdisciplinary approaches, and knowledgeable and experienced researchers and industry practitioners). For these reasons, the selected DSRM was appropriate for guiding the research process.

In DSR, the quality of research corresponds directly to the quality of the process by means of which the research was produced (Vom Brocke, et al., 2020). To ensure that "good" quality DSR is conducted, Hevner, et al. (2004, p.77) provides seven guidelines from which research can be evaluated. These seven guidelines and their application to this research were outlined in Chapter 2 (Section 2.4.1). To reflect and assess whether a rigorous DSRM was applied, these guidelines are revisited in Table 11.1, in retrospect of the research chapters.

*Table 11. 2: Design Science Research Guidelines [Source: Researcher's own construction, informed by Hevner, et al. (2004) and Vaishnavi, Kuechler and Petter (2017)]*

| DSR Guideline | Application of DSR Guideline to Artefact (Framework) Design |
|---|---|
| **Guideline 1: Design as an Artefact**<br>DSR should produce a viable artefact in the form of a construct, method, model, instantiation, design theory, framework, architecture or design principles. | • The Interdisciplinary mHealth App Design Framework (Chapter 7 and 10) is the primary design artefact (Section 11.3.1), which adopts a novel boundary object view (Section 11.3.3, Chapter 5) that highlights the value in using and creating boundary objects and supporting artefacts to guide, facilitate and mediate heteropraxial activities and knowledge sharing practices between heterogeneous communities during the design, development and evaluation project process of mHealth physical activity behaviour change intervention consumer apps. |

| | |
|---|---|
| **Guideline 2: Problem Relevance**<br>DSR should produce technology-based solutions that aim to address relevant and practical, real world problems. | • In light of the global NCD and physical inactivity pandemics, mobile app technology provides a powerful means of delivering health promotion physical activity behaviour change interventions to individuals at the dual intra-interpersonal socioecological levels (Chapters 3 and 4). However, there are several key challenges regarding the design of mHealth (physical activity) behaviour change intervention apps, and the root problem lies in the paucity of multi- and interdisciplinary approaches for guiding and supporting project teams during the collaborative design, development and evaluation process (Section 11.3.1, Chapter 4). The use and creation of various boundary objects and supporting artefacts can improve the interdisciplinary collaborative process, resulting in better designed and more effective consumer app product solutions (Chapter 5). |
| **Guideline 3: Design Evaluation**<br>The utility, quality and trustworthiness of a design artefact should be demonstrated using well-executed evaluation methods. | • The quality and trustworthiness of the proposed conceptual framework was evaluated using a qualitative DSR linguistic interpretivist approach, which involved conducting virtual semi-structured interviews with 31 knowledgeable and experienced researchers and industry practitioners spanning ten international countries, in order to interpersonally verify the construction adequacy, language adequacy and clarity of the framework and its components (Section 11.3.3, Chapters 8 and 9). The interview evaluation study findings informed the revision and modification of the enhanced Interdisciplinary mHealth App Design Framework artefact contribution (Chapter 10). |
| **Guideline 4: Research Contributions**<br>DSR should provide clear and verifiable contributions in the areas of the design artefact itself, design foundations and/or design methodologies. | • The enhanced Interdisciplinary mHealth App Design Framework provides a novel artefact contribution at "Level 2" (Figure 11.2) in "improvement" quadrant (Figure 11.3) (Chapter 10). The tri-composite theoretical framework (boundary object view) provides a novel solution perspective (Chapter 5). Four additional theoretical contributions are made to the mHealth intervention app design body of knowledge (Section 11.3.1, Chapters 4, 6 and 9). Practical contributions are made in terms of practical guideline recommendations and proof of concept (Section 11.3.2, Chapters 7 and 10) and methodological contributions are made in terms of DSR construction and evaluation knowledge (Section 11.3.3, Chapters 6, 8, 9 and 10). |
| **Guideline 5: Research Rigour**<br>DSR should apply rigorous methods during the construction and evaluation of a design artefact. | • The key boundary object view components of the proposed conceptual framework were elicited from twenty existing multi- and interdisciplinary digital health intervention development approaches (categorised into four perspectives), using a critical thematic and comparative theoretical analysis approach, in conjunction with Weick's (1989) theorising process and a hybrid cognitive reasoning strategy (Chapter 6). The secondary dataset was selected using Boell and Cecez-Kecmanovic's (2010; 2014) hermeneutic search and acquisition approach, which is particularised to the information systems discipline (Section 11.3.3, Chapter 6). The initial conceptual framework (Chapter 7) was informed by the critical theoretical analysis findings (Chapter 6) and literature reviews (Chapters 3 and 4). The framework was rigorously evaluated with knowledgeable and experienced researchers and industry practitioners to assess, determine and improve its quality and reflection of real world practice (Chapters 9 and 10). |
| **Guideline 6: Design as a Search Process**<br>The search for a satisficing design artefact utilises available means to reach desired ends while satisfying laws in the problem environment. | • The framework components were informed by the findings from literature and a thorough critical theoretical analysis on twenty existing multi- and interdisciplinary digital health intervention approaches (Chapters 3, 4, 6 and 7). The interview evaluation study interpersonally verified and informed the modification and revision of the enhanced framework's components (and subcomponents), and confirmed the domain ontology and contextual relevance and significance of the framework in reflecting real world practice in research and industry (Chapter 10). |
| **Guideline 7: Communication of Research**<br>DSR should be presented clearly and effectively to technology-orientated and practice-orientated audiences. | • The process of developing and evaluating the Interdisciplinary mHealth App Design Framework is clearly and explicitly described and justified (Chapters 6, 7, 8, 9 and 10). The novel boundary object view solution perspective is clearly and explicitly described and justified as a suitable innovative approach to addressing the real world complex design problem (Chapter 5). The main and supplementary components (and subcomponents) of the initial conceptual and revised enhanced framework are clearly and explicitly communicated (Chapters 7 and 10). |

In addition to Hevner's (2004) guidelines, Gregor and Hevner (2013, p.349) provide a communication and publication schema, which can be used to evaluate whether a DSR project makes a "contribution to generalised knowledge" and has been explicitly and effectively communicated. These seven schema and their application to this research were outlined in Chapter 2 (Section 2.4.2). To reflect and assess whether a rigorous DSRM was applied, these schema are briefly revisited in Table 11.2, in retrospect of the research chapters.

*Table 11.2: Communication and Publication Schema for an Information Systems DSR Project [Source: Adapted from Gregor and Hevner (2013)]*

| Section of DSR Project | Contents of Section |
|---|---|
| **1. Introduction** | The introduction was presented in Chapter 1, outlining the research problem, questions and objectives, significance, scope, methods, results and overall project structure. |
| **2. Literature Review** | The literature reviews were performed in Chapters 3 and 4, which provided the key contextual landscape information relevant to the environment/domain and knowledge base. |
| **3. Method** | The overall research structure and process was presented in Chapter 2, outlining the paradigmatic philosophy and DSRM. The research methodology used to evaluate the framework was outlined in Chapter 8, and the process used to revise the enhanced framework was outlined in Chapter 10. |
| **4. Artefact Description** | The initial framework artefact is clearly detailed in Chapter 7 and the revised and enhanced Interdisciplinary mHealth App Design Framework is clearly described in Chapter 10. |
| **5. Evaluation** | The approach and quality criteria used to evaluate the artefact was outlined in Chapter 8 and revisited in Chapter 10. |
| **6. Discussion** | The interview evaluation study findings and discussion were clearly communicated in Chapter 9, using excerpt evidence from the data, and findings were related back to literature. |
| **7. Conclusions** | The conclusion is presented in this chapter, Chapter 11, which revisits and answers the research questions, and clearly outlines the research contributions, implications, reflections, limitations and suggestions for future research. |

### 11.5.3 Self-Reflections and Lessons Learned

In the pragmatic paradigm, self-reflections are performed in terms of intuitions, actions and practical experience (Lynch and Metcalfe, 2006; Mortari, 2015). From the onset of the research journey, the researcher was motivated to pursue the problem area out of their own personal interest in health and wellness, psychology, and digital technology. The problem thesis arose out of the researcher's prolonged engagement with literature (for several years), as well as their international student exchange experience, in which they participated in certified training workshops, visited various hospitals, clinics and health centres, met with researchers and practitioners in digital health, and attended international digital health conferences. The novel tentative design solution suggestion was largely driven by intuition; an intuitive "hunch" that the use and creation of boundary objects and supporting artefacts would be key to supporting knowledge sharing practices and interdisciplinary design collaboration (Dewey, 1931, p.100),

and a bewilderment that such a simple solution perspective had not yet been considered in addressing the problem spurred further curiosity and investigation.

The researcher's ongoing and evolving understanding of the problem and solution space was informed by extensive reviews of literature at the nexus of the intersecting diverse disciplines, as well as their background qualifications and certifications in information systems (with courses in user interface and user experience design), creative design, physical activity training, and psychology (with courses in health psychology). Upon reflection, the process of clearly identifying and defining the problem statement could have been established earlier and quicker, considering that the core problem focus was remoulded a few times during the research journey. Given the newly emerging complexities of the interdisciplinary arena over the last several years, defining the current problem focus was largely driven by a process of navigating through continuous exploration, discovery and (re)learning.

In terms of the artefact development and evaluation process, various lessons were learned when executing the critical theoretical analysis and the interview evaluation study. Upon reflection, the ethical application and approval process could have been performed at an earlier stage so that the interview evaluation study took place in 2020 and not 2021. In addition, continuous "reflections-on-action" have yielded lessons learned regarding the conducting and writing up of critical theoretical analysis (secondary data) and qualitative empirical study (primary data) findings and discussions (Lynch and Metcalfe, 2006, p.8), with exercises in refraining from performing and reporting on work that is too analytical and detail orientated. Moreover, in terms of the DSRM and its emphasis on practical contributions, the researcher was left with the dilemma that the research largely contributes on a theoretical and methodological level. Although the practical value of the framework has been argued in proof of concept, its utility has not yet been demonstrated through application in real world practice. To bridge this theory-practice divide, guideline recommendations for applying the framework components were proposed, although future work is required in developing a researcher and practitioner's guide that supports the framework's pragmatic application for real world practice.

## 11.6 Limitations

The limitations identified in this research concern: the theoretical structure of the framework; the framework's practical application; the scoped disciplinary contributions; and the delineated framework context.

***Theoretical Structure of Framework***

The theoretical structure of the Interdisciplinary mHealth App Design Framework could be enhanced through the critical analysis of more multi- and interdisciplinary digital health intervention development approaches. This study only included twenty existing approaches, and since performing the critical theoretical analysis, three new and valuable approaches have been proposed in the literature, namely Sucala, et al.'s (2020) *Iterative, Interdisciplinary, Collaborative Framework for Developing and Evaluating Digital (Health) Behaviour Change Interventions*, Kowatsch, et al.'s (2019) *Design and Evaluation Framework for Digital Health Interventions*, and Blandford's (2019b) *Integrated Development Lifecycle for Digital Health Technologies*. In light of this limitation, although these approaches were not included in the critical theoretical analysis, they were reviewed and incorporated into the research literature and framework's development. On an additional note, the range of multi- and interdisciplinary approaches reviewed could be expanded beyond the four Health, Information Systems/ Technology, Partnership and Integrative Perspective categories, to include computer science, artificial intelligence, business, product development, economic and marketing perspectives.

***Practical Application of the Framework***

As already highlighted, the Interdisciplinary mHealth App Design Framework has not been applied or demonstrated in real world practice settings. Although guideline recommendations for application have been proposed to bridge the theory-practice gap, the practical contributions of the research could have been enriched by applying the framework, for instance, to one or more specific case study mHealth intervention app project settings or contexts. This practical application could be performed by researchers and/or industry practitioners. The findings accruing from the framework's practical application could inform its further revision and enhancement, as well as its generalisation to other health behaviour contexts.

***Scoped Disciplinary Contributions***

This research contributes primarily to the information systems field, and partially contributes to knowledge in the health behavioural sciences, health psychology, and persuasive systems design communities. As explicitly stipulated and justified in Chapter 7 (Subsection 7.3.1.1), this research and the Interdisciplinary mHealth App Design Framework acknowledges the pertinence of the "computer science" and "business" practice communities, and incorporates them into the framework's "actors" component; however, this research does not formally

contribute knowledge to these fields. By giving more focus to the roles and contributions provided by these two communities, the framework could be further improved and enhanced.

***Delineated Framework Context***

In terms of environment and application domain (Hevner, 2007), the Interdisciplinary mHealth App Design Framework is delineated to the physical activity context and the dual intra-interpersonal socioecological levels of health promotion (as outlined in Chapter 3). The reason for this is that the health behaviour change theories, determinants and correlates, mechanisms of action, BCTs, PSD principles, and the translated and operationalised app interface design features can differ considerably depending on the intervention's target health behaviour and audience. It was therefore decided that a particular health behaviour and socioecological level of intervention would be delineated when reviewing literature and developing and evaluating the framework. By incorporating literature on other key modifiable health risk behaviours, such as unhealthy eating, insufficient sleep, harmful alcohol consumption and tobacco use (WHO, 2010a; 2018a), and by targeting other (or additional) socioecological levels of health promotion, such as either one (or a combination) of the organisational, community, societal or supranational levels (Chapter 3, Figure 3.2), the Interdisciplinary mHealth App Design Framework could be further enhanced and generalised. Moreover, by investigating and integrating collaborative processes and practices pertaining to other digital platforms, such as websites, the framework could be further enhanced and generalised to more contexts.

## 11.7 Future Research

Future research can be conducted on: further enhancing the theoretical structure of the framework; applying the framework in practice; expanding on disciplinary contributions; expanding on the framework's contextual relevance; further investigating the framework's components; and further exploring key challenges and opportunities for future improvement.

***Enhancing the Theoretical Structure of the Framework***

Additional and more recently published multi- and interdisciplinary digital health intervention development approaches can be included in future critical theoretical analyses to enhance the theoretical structure of the framework. Incorporating theories, models and frameworks from the domain of physical activity, exercise and sport sciences can also contribute to the framework's theoretical structure. In addition to the Health, Information Systems/Technology,

Partnership and Integrative Perspective categories, other approaches from the computer sciences and business perspectives can be incorporated into future critical theoretical analyses to further expand and enrich the theoretical structure of the framework.

***Applying the Framework in Practice***

Future research can apply the Interdisciplinary mHealth App Design Framework in real world practice settings. For example, demonstrating the framework in one or more specific case study mHealth intervention app project settings or contexts. Applying the framework in practice can be carried out by researchers and/or industry practitioners, which can yield valuable insights in terms of how useful or viable the framework is in guiding and supporting real world practice for research, industry or academia-industry collaboration projects. Furthermore, future research can refine the proposed practical guideline recommendations and develop a researcher and practitioner's guide for supporting the framework's pragmatic application.

***Expanding Contributions to Relevant Disciplines***

Further exploring and investigating the boundary objects and supporting artefacts, design, development and evaluation processual activities, and knowledge sharing practices of the computer sciences and business practice communities can contribute knowledge to these two disciplines, and enhance the overall comprehensiveness and quality of the framework. Any other disciplines identified as necessary and pertinent to the successful production of effective mHealth behaviour change intervention apps can also be explored and investigated.

***Expanding the Framework's Contextual Relevance***

The framework can be further expanded and generalised to inform the design, development and evaluation of mHealth intervention apps for other modifiable health (promotion) behaviour change contexts (such as unhealthy eating, insufficient sleep, harmful alcohol consumption and tobacco use), and other socioecological levels of health promotion (such as the organisational, community, societal or supranational levels). Furthermore, the framework can be expanded and generalised to inform the design, development and evaluation of other modes of digital intervention delivery (such as websites).

***Continued Investigation into the Framework Components***

Future research can continue investigating and expanding on the framework's main components. This is particularly with regard to the *"knowledge"* component, considering that the interview participants frequently confirmed and discussed challenges relating to knowledge sharing, knowledge boundaries and developing shared understandings, yet when asked how to overcome such challenges, often resorted to answers such as "it just boils down to communication" and "don't be afraid to ask questions and learn". While open communication and continuous enquiry is important for effective interdisciplinary team collaboration, future research should explore more innovative ways of supporting and overcoming knowledge related challenges. In addition, considering that the Interdisciplinary mHealth App Design Framework approaches knowledge from a pragmatic perspective (although it incorporates processual, dynamic and boundary object relational perspectives), future research can investigate addressing knowledge challenges from interactionist (Tell, et al., 2017), communication (Mengis, 2007), or dialogical (Tsoukas, 2009) perspectives. Similarly, the framework's main *"actors"*, *"boundary objects and supporting artefacts"* and *"interdisciplinary collaborative process"* components can also be further explored and expanded in future research.

***Exploring and Investigating Key Challenges and Opportunities for Future Improvement***

The interview study findings revealed six key challenges and opportunities pertaining to mHealth (physical activity) behaviour change intervention app projects that future research can reference and further investigate. These key challenges and opportunities were reported in detail in Chapter 9 (Section 9.4.7) and cover the following topics: (1) mHealth physical activity app projects; (2) interdisciplinary collaborating teams; (3) the interdisciplinary collaborative process; (4) funding and investments; (5) the divide between academia/research and industry; and (6) current and future advancements in the mHealth physical activity behaviour change intervention app field.

## 11.8 Concluding Remarks

Digital mobile app technology provides a powerful and increasingly popular means of delivering health promotion behaviour change interventions to individuals across the globe, such as those targeting physical activity. Yet, despite the vast opportunities and capabilities of mHealth behaviour change intervention consumer apps, there exist several key design

challenges that influence the effectiveness of said apps, presenting a complex multifaceted and wicked design problem. At the root and heart of this design problem there exists a paucity of multi- and interdisciplinary collaborative approaches for guiding and supporting the synergistic amalgamation and integration of heterogeneous knowledge, expertise, skills and practices from multiple relevant disciplines (Blandford, et al., 2018; Kowatsch, et al., 2019; Taj, Klein and van Halteren, 2019; Van Gemert-Pijnen, et al., 2018; Walsh and Groarke, 2019; Bendtsen, et al., 2020; Hermsen, et al, 2020).

Adopting a boundary object view, which emphasises the use and creation of boundary objects and supporting artefacts by interdisciplinary project teams in guiding and supporting their heteropraxial activities and knowledge sharing practices during the collaborative design, development and evaluation process, can result in more innovative and effective mHealth (physical activity) behaviour change intervention app product design solutions. Furthermore, it is imperative that the indispensable role and significance of all six relevant actor, object/artefact, knowledge, process activity, outcome and project boundary components, and their complex and intricate entanglement, be considered in carrying out successful mHealth intervention app projects. An Interdisciplinary mHealth App Design Framework that incorporates these elements, and guides and supports project teams during the interdisciplinary collaborative design, development and evaluation process can improve the innovativeness and effectiveness of mHealth (physical activity) behaviour change intervention consumer app product solutions, and help motivate and empower more people to sustainably change their modifiable health risk behaviours and lead healthier lifestyles, thereby fighting and reducing the wide-spread prevalence of NCDs, the world's leading cause of premature mortality.

As part of the continued enhancement of the Interdisciplinary mHealth App Design Framework, it should be practically applied to a variety of case study project contexts, of which the accrued and analysed findings can further inform its revision, modification and generalisation to suit other digital platform and health behaviour contexts, befitting real world research and industry practice.

*If I had my way*

*[The world] would be different*

*Strangers would be kinder*

*As it saved the day*

…

*If I had my way*

*The milk of human kindness*

*Would seek us out and find us*

*And colour all the words we say*

…

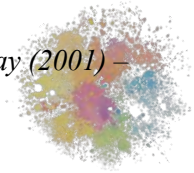
*Hearts would come alive*

*Instead of breaking*

*Faith would not betray*

*If I had my way*

*– Linda Eder, If I Had My Way (2001) –*



# *Gold*

*– Linda Eder (2002) –*

*I wonder if*
*When all is done*
*Anyone heard my voice*
*But from the start*
*We have no choice*
*Our journeys just begin*

*I'll never know if I was right*
*Did I fight hard enough?*
*When the battles grew too rough*
*Should I have given in?*

*But here I stand and swear to you*
*I did the best that I could do*

*I know my voice was just a whisper*
*But someone may have heard*
*There were nights the moon above me stirred,*
*And let me grab a hold*
*My hands have touched the gold*

*My heart's been driven by extremes*
*Blind with dreams, tight with fear*
*But still God knows that I was here*
*And I was so alive*

*And now I lay the past to rest*
*For in the end I did my best*

*You have to live the life you're given*
*And never close your eyes*
*You hold on, and stare into the skies,*
*And burn against the cold*
*For any moment,*
*You might find the gold!*

*And there was joy*
*Through it all*
*And I am standing tall*

*I know my voice was just a whisper*
*But someone must have heard*
*There were nights the moon above me stirred,*
*And let my light take hold*
*I rode across that sky*
*And once I touched the gold*

*Here in my own two hands*
*I once held the gold*

*Caroline and Jane,*
*Thank you for hearing my voice.*

# References

Abdi, J., Eftekhar, H., Estebsari, F. and Sadeghi, R. (2015). Theory-Based Interventions in Physical Activity: A Systematic Review of Literature in Iran. *Global Journal of Health Science*, 7(3), pp.215–229.

Abraham, A. (2015). *Development of Design Principles for Boundary Objects in Enterprise Transformation*. PhD. University of St. Gallen.

Abraham, C. and Sheeran, P. (2015). The Health Belief Model. In: M. Conner and P. Sheeran, eds., *Predicting and Changing Health Behaviour. 3rd ed.* Maidenhead: Open University Press, pp.30–69.

Abula, K., Gröpel, P., Chen, K. and Beckmann, J. (2018). Does Knowledge of Physical Activity Recommendations Increase Physical Activity Among Chinese College Students? Empirical Investigations Based on the Transtheoretical Model. *Journal of Sport and Health Science*, 7(1), pp.77–82.

Ács, P., Kovács, A., Paár, D., Hoffbauer, M., Szabó, P., Szabó, T. and Stocker, M. (2020). Comparative Analysis of the Economic Burdens of Physical Inactivity in Hungary Between 2005 and 2017. *BMC Public Health*, 20(S1), pp.1174–1182.

Adom, D., Hussein, E.K. and Agyem, J.A. (2018). Theoretical and Conceptual Framework: Mandatory Ingredients of a Quality Research. *International Journal of Scientific Research*, 7(1), pp.438–441.

Adom, D., Osei, M. and Adu-Agyem, J. (2020). COVID-19 Lockdown: A Review of an Alternative to the Traditional Approach to Research. *Research Journal in Advanced Social Sciences*, [online] 1, pp.1–9. Available at: https://royalliteglobal.com/rjass/article/view/107 [Accessed 17 Jul. 2021].

African Physical Activity Network (2020). *Physical Activity for Health in Africa: Guidance During and Beyond the COVID-19 Pandemic*. Cape Town: Western Cape Goverment.

Agarwal, S., LeFevre, A.E., Lee, J., L'Engle, K., Mehl, G., Sinha, C. and Labrique, A. (2016). Guidelines for Reporting of Health Interventions Using Mobile Phones: Mobile Health (mHealth) Evidence Reporting and Assessment (mERA) Checklist. *BMJ*, 352, pp.1–10.

Aguilera, A., Figueroa, C.A., Hernandez-Ramos, R., Sarkar, U., Cemballi, A., Gomez-Pathak, L., Miramontes, J., Yom-Tov, E., Chakraborty, B., Yan, X., Xu, J., Modiri, A., Aggarwal, J., Williams, J. and Lyles, C.R. (2020). mHealth App Using Machine Learning to Increase Physical Activity in Diabetes and Depression: Clinical Trial Protocol for the DIAMANTE Study. *BMJ Open*, 10(8), p.e034723.

Ajzen, I. (1991). The Theory of Planned Behaviour. *Organisational Behaviour and Human Decision Processes*, 50(2), pp.179–211.

Ajzen, I. and Fishbein, M. (2000). Attitudes and the Attitude-Behaviour Relation: Reasoned and Automatic Processes. *European Review of Social Psychology*, 11(1), pp.1–33.

Akkerman, S.F. and Bakker, A. (2011). Boundary Crossing and Boundary Objects. *Review of Educational Research*, 81(2), pp.132–169.

Al Ayubi, S.U., Parmanto, B., Branch, R. and Ding, D. (2014). A Persuasive and Social mHealth Application for Physical Activity: A Usability and Feasibility Study. *JMIR mHealth and uHealth*, 2(2), p.e25.

Alahäivälä, T., Oduor, M. and Oinas-Kukkonen, H. (2014). A Reward Design Pattern in BCSS. In: *Second International Workshop on Behaviour Change Support Systems (BCSS 2014)*. [online] Available at: https://www.semanticscholar.org/paper/A-Reward-Design-Pattern-in-BCSS-Alah%C3%A4iv%C3%A4l%C3%A4-Oduor/60ef0aa8bb62a479237d54e175d542c121ec93bd [Accessed 16 Jul. 2021].

Aldenaini, N., Oyebode, O., Orji, R. and Sampalli, S. (2020). Mobile Phone-Based Persuasive Technology for Physical Activity and Sedentary Behaviour: A Systematic Review. *Frontiers in Computer Science*, 2, pp.1–17.

Aleksovska, K., Puggina, A., Giraldi, L., Buck, C., Burns, C., Cardon, G., Carlin, A., Chantal, S., Ciarapica, D., Colotto, M., Condello, G., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J. and Izzicupo, P. (2019). Biological Determinants of Physical Activity Across the Life Course: A "Determinants of Diet and Physical Activity" (DEDIPAC) Umbrella Systematic Literature Review. *Sports Medicine Open*, 5(1), pp.1–18.

Alessa, T., S Hawley, M., Alsulamy, N. and de Witte, L. (2021). Using a Commercially

Available App for Self-Management of Hypertension: Acceptance and Usability Study in Saudi Arabia. *JMIR mHealth and uHealth*, 9(2), p.e24177.

Allen, J.K., Stephens, J., Dennison Himmelfarb, C.R., Stewart, K.J. and Hauck, S. (2013). Randomised Controlled Pilot Study Testing Use of Smartphone Technology for Obesity Treatment. *Journal of Obesity*, 2013, pp.1–7.

Allen, L. (2017). Are we Facing a Noncommunicable Disease Pandemic? *Journal of Epidemiology and Global Health*, 7(1), pp.5–9.

Almutari, N. and Orji, R. (2019). How Effective Are Social Influence Strategies in Persuasive Apps for Promoting Physical Activity? In: *Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalisation - UMAP'19 Adjunct*. [online] pp.1–6. Available at: https://dl.acm.org/doi/abs/10.1145/3314183.3323855 [Accessed 17 Jul. 2021].

Althoff, T., White, R.W. and Horvitz, E. (2016). Influence of Pokémon Go on Physical Activity: Study and Implications. *Journal of Medical Internet Research*, 18(12), p.e315.

Alturki, A. (2012). A Design Science Research Roadmap. In: *PACIS 2012 Proceedings*. [online] pp.1–10. Available at: https://aisel.aisnet.org/pacis2012/190/ [Accessed 15 Jul. 2021].

Alturki, A. and Gable, G. (2014). Theorising in Design Science Research: An Abstraction Layers Framework. In: *PACIS 2014 Proceedings*. [online] pp.1–15. Available at: https://aisel.aisnet.org/pacis2014/126/ [Accessed 15 Jul. 2021].

Alturki, A., Gable, G.G. and Bandara, W. (2011). A Design Science Research Roadmap. In: *Service-Oriented Perspectives in Design Science Research- International Conference on Design Science Research in Information Systems (DESRIST) 2011 Proceedings*. [online] pp.107–123. Available at: https://link.springer.com/chapter/10.1007/978-3-642-20633-7_8 [Accessed 15 Jul. 2021].

Alturki, R. and Gay, V. (2017). Usability Testing of Fitness Mobile Application: Methodology and Quantitative Results. In: *Computer Science & Information Technology (CS & IT)*. pp.97–114.

Amimo, F., Lambert, B. and Magit, A. (2020). What Does the COVID-19 Pandemic Mean for HIV, Tuberculosis, and Malaria Control? *Tropical Medicine and Health*, 48(1), pp.1–4.

Amzat, J. and Razum, O. (2014). Health, Disease, and Illness as Conceptual Tools. In: J. Amzat and O. Razum, eds., *Medical Sociology in Africa*. Switzerland: Springer International Publishing, pp.21–37.

Angosto, S., García-Fernández, J., Valantine, I. and Grimaldi-Puyana, M. (2020). The Intention to Use Fitness and Physical Activity Apps: A Systematic Review. *Sustainability*, 12(16), p.6641.

Angus, K., Cairns, G., Purves, R., Bryce, S., Macdonald, L. and Gordon, R. (2013). *Systematic Literature Review to Examine the Evidence for the Effectiveness of Interventions that Use Theories and Models of Behaviour Change: Towards the Prevention and Control of Communicable Diseases*. [online] Solna: European Centre for Disease Prevention and Control (ECDC). Available at: https://www.semanticscholar.org/paper/Systematic-literature-review-to-examine-the-for-the-Angus-Cairns/1ae83d2c460bda06509b25ab7cc59a5f9e854e7a.

Apple App Store (2021). *Apple App Store: Apps on iTunes*. [online] Apple App Store. Available at: https://apps.apple.com/us/genre/ios/id36 [Accessed 16 Jul. 2021].

Apptopia (2021). *Top Overall iOS and Google Play Apps Worldwide*. [online] Apptopia. Available at: https://apptopia.com/store-insights/top-charts/itunes-connect/health-fitness/united-states [Accessed 16 Jul. 2021].

Archibald, M.M., Ambagtsheer, R.C., Casey, M.G. and Lawless, M. (2019). Using Zoom Videoconferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. *International Journal of Qualitative Methods*, 18(1), pp.1–8.

Arigo, D., Jake-Schoffman, D.E., Wolin, K., Beckjord, E., Hekler, E.B. and Pagoto, S.L. (2019). The History and Future of Digital Health in the Field of Behavioural Medicine. *Journal of Behavioural Medicine*, 42(1), pp.67–83.

Arjoranta, J., Kari, T. and Salo, M. (2020). Exploring Features of the Pervasive Game Pokémon GO That Enable Behaviour Change: Qualitative Study (Preprint). *JMIR Serious Games*,

8(2).

Atkin, A.J., van Sluijs, E.M.F., Dollman, J., Taylor, W.C. and Stanley, R.M. (2016). Identifying Correlates and Determinants of Physical Activity in Youth: How Can We Advance the Field? *Preventive Medicine*, 87, pp.167–169.

Avenier, M. and Thomas, C. (2015). Finding One's Way Around Various Methodological Guidelines for Doing Rigorous Case Studies: A Comparison of Four Epistemological Frameworks. *Systèmes d'Information et Management*, 20(1), pp.61–98.

Aydin, G. and Silahtaroglu, G. (2021). Insights into Mobile Health Application Market via a Content Analysis of Marketplace Data with Machine Learning. *PLOS ONE*, 16(1), p.e0244302.

Baduza, G. (2020). *A Comprehensive Approach to Scalability Assessment of ICTD Projects in South Africa*. PhD. Rhodes University.

Baehr, M. (2004). *Evaluation Methodology*. Elmhurst: Pacific Crest, pp.1–4.

Bakker, A. and Akkerman, S.F. (2014). A Boundary-Crossing Approach to Support Students' Integration of Statistical and Work-Related Knowledge. *Educational Studies in Mathematics*, 86(2), pp.223–237.

Bandura, A. (1977). Self-Efficacy: Toward a Unifying Theory of Behavioural Change. *Psychological Review*, 84(2), pp.191–215.

Bandura, A. (1998). Health Promotion from the Perspective of Social Cognitive Theory. *Psychology & Health*, 13(4), pp.623–649.

Bandura, A. (1999). Social Cognitive Theory of Personality. In: L.A. Pervin and O.P. John, eds., *Handbook of Personality: Theory and Research*. Guilford Press, pp.154–196.

Bardus, M., van Beurden, S.B., Smith, J.R. and Abraham, C. (2016). A Review and Content Analysis of Engagement, Functionality, Aesthetics, Information Quality, and Change Techniques in the Most Popular Commercial Apps for Weight Management. *International Journal of Behavioural Nutrition and Physical Activity*, 13(1).

Baretta, D., Perski, O. and Steca, P. (2019). Exploring Users' Experiences of the Uptake and

Adoption of Physical Activity Apps: Longitudinal Qualitative Study. *JMIR mHealth and uHealth*, 7(2), p.e11636.

Barker, R.G. (1968). *Ecological Psychology: Concepts and Methods for Studying the Environment of Human Behaviour*. Stanford, CA: Stanford University Press.

Bartholomew Eldredge, L.K., Markham, C.M., Ruiter, R.A.C., Fernández, M.E., Kok, G. and Parcel, G.S. (2016). *Planning Health Promotion Programs: An Intervention Mapping Approach*. 4th ed. San Francisco: Jossey-Bass.

Bartholomew, L.K., Parcel, G.S., Kok, G. and Gottlieb, N.H. (2006). *Planning Health Promotion Programs: An Intervention Mapping Approach*. San Francisco: Jossey-Bass.

Bartlett, Y.K., Webb, T.L. and Hawley, M.S. (2017). Using Persuasive Technology to Increase Physical Activity in People with Chronic Obstructive Pulmonary Disease by Encouraging Regular Walking: A Mixed-Methods Study Exploring Opinions and Preferences. *Journal of Medical Internet Research*, 19(4), p.e124.

Basballe, D.A. and Halskov, K. (2012). Dynamics of Research Through Design. *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. [online] Available at: https://dl.acm.org/doi/10.1145/2317956.2317967 [Accessed 15 Jul. 2021].

Baskerville, R. and Pries-Heje, J. (2010). Explanatory Design Theory. *Business & Information Systems Engineering*, 2(5), pp.271–282.

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A. and Rossi, M. (2018). Design Science Research Contributions: Finding a Balance between Artifact and Theory. *Journal of the Association for Information Systems*, 19(5), pp.358–376.

Bauman, A.E., Reis, R.S., Sallis, J.F., Wells, J.C., Loos, R.J. and Martin, B.W. (2012). Correlates of Physical Activity: Why Are Some People Physically Active and Others Not? *The Lancet*, 380(9838), pp.258–271.

Bauman, A.E., Sallis, J.F., Dzewaltowski, D.A. and Owen, N. (2002). Toward a Better Understanding of the Influences on Physical Activity. *American Journal of Preventive Medicine*, 23(2), pp.5–14.

Bearne, L.M., Sekhon, M., Grainger, R., La, A., Shamali, M., Amirova, A., Godfrey, E.L. and

White, C.M. (2020). Smartphone Apps Targeting Physical Activity in People with Rheumatoid Arthritis: Systematic Quality Appraisal and Content Analysis. *JMIR mHealth and uHealth*, 8(7), pp.1–13.

Beauchamp, M.R., Crawford, K.L. and Jackson, B. (2019). Social Cognitive Theory and Physical Activity: Mechanisms of Behaviour Change, Critique, and Legacy. *Psychology of Sport and Exercise*, 42, pp.110–117.

Beck, R., Weber, S. and Gregory, R. (2013). Theory-Generating Design Science Research. *Inf. Syst. Frontiers*, 15, pp.637–651.

Becker, J. and Niehaves, B. (2007). Epistemological Perspectives on IS Research: A Framework for Analysing and Systematizing Epistemological Assumptions. *Information Systems Journal*, 17(2), pp.197–214.

Becker, J., Niehaves, B. and Pfeiffer, D. (2008a). Ontological Evaluation of Conceptual Models. *Scandinavian Journal of Information Systems*, 20(2), pp.83–110.

Becker, J., Niehaves, B. and Pfeiffer, D. (2008b). Towards a Holistic Approach to Validating Conceptual Models. In: P. Johannesson and E. Soderstrom, eds., *Information Systems Engineering: From Data Analysis to Process Networks: From Data Analysis to Process Networks*. New York: IGI Publishing, pp.229–251.

Becker, M.H. (1974). The Health Belief Model and Sick Role Behaviour. *Health Education Monographs*, 2(4), pp.409–419.

Bendtsen, M., Bendtsen, P., Henriksson, H., Henriksson, P., Müssener, U., Thomas, K. and Löf, M. (2020). The Mobile Health Multiple Lifestyle Behaviour Interventions Across the Lifespan (MoBILE) Research Program: Protocol for Development, Evaluation, and Implementation. *JMIR Research Protocols*, 9(4), pp.1–12.

Bennett, J.E., Kontis, V., Mathers, C.D., Guillot, M., Rehm, J., Chalkidou, K., Kengne, A.P., Carrillo-Larco, R.M., Bawah, A.A., Dain, K., Varghese, C., Riley, L.M., Bonita, R., Kruk, M.E., Beaglehole, R. and Ezzati, M. (2020). NCD Countdown 2030: Pathways to Achieving Sustainable Development Goal Target 3.4. *The Lancet*, 396(10255), pp.918–934.

Ben-Zeev, D., Schueller, S.M., Begale, M., Duffecy, J., Kane, J.M. and Mohr, D.C. (2015). Strategies for mHealth Research: Lessons from 3 Mobile Intervention Studies. *Administration and Policy in Mental Health and Mental Health Services Research*, 42(2), pp.157–167.

Bergman, M., Lyytinen, K. and Gloria, M. (2007). Boundary Objects in Design: An Ecological View of Design Artifacts. *Journal of the Association for Information Systems*, 8(11), pp.546–568.

Bergold, J. and Thomas, S. (2012). Participatory Research Methods: A Methodological Approach in Motion. *Historical Social Research*, [online] 13(1), pp.191–222. Available at: https://doi.org/10.12759/hsr.37.2012.4.191-222 [Accessed 16 Jul. 2021].

Berkley, S., Bobadilla, J., Hecht, R., Hill, K., Jamison, D.T., Murray, C.J.L., Musgrove, P., Saxenian, H. and Tan, J. (1993). *World Development Report 1993: Investing in Health - World Development Indicators*. Washington, DC: World Bank Group.

Berkovsky, S., Coombe, M., Freyne, J., Bhandari, D. and Baghaei, N. (2010). Physical Activity Motivating Games: Virtual Rewards for Real Activity. In: *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10*.

Bertelsen, O. (2000). Design Artefacts: Towards a Design-Oriented Epistemology. *Scandinavian Journal of Information Systems*, [online] 12(1), pp.15–27. Available at: https://aisel.aisnet.org/sjis/vol12/iss1/2 [Accessed 16 Jul. 2021].

Bertelsen, O.W. (1998). *Elements of a Theory of Design Artefacts: A Contribution to Critical Systems Development Research*. PhD. Aarhus University.

Bhattacherje, A. (2012). *Social Science Research: Principles, Methods, and Practices*. 2nd ed. Florida: Global Text Project.

Biagianti, B., Hidalgo-Mazzei, D. and Meyer, N. (2017). Developing Digital Interventions for People Living with Serious Mental Illness: Perspectives from Three mHealth Studies. *Evidence Based Mental Health*, 20(4), pp.98–101.

Bice, T.W. (1976). Comments on Health Indicators: Methodological Perspectives. *International Journal of Health Services*, 6(3), pp.509–520.

Biddle, S.J.H., Mutrie, N., Gorely, T. and Faulkner, G. (2021). *Psychology of Physical Activity Determinants, Well-Being and Interventions*. 4th ed. New York: Routledge.

Bielik, P., Tomlein, M., Krátky, P., Mitrík, Š., Barla, M. and Bieliková, M. (2012). Move2Play: An Innovative Approach to Encouraging People to be More Physically Active. In: *Proceedings of the 2nd ACM SIGHIT Symposium on International Health Informatics - IHI '12*.

Bircher, J. (2005). Towards a Dynamic Definition of Health and Disease. *Medicine, Health Care and Philosophy*, 8(3), pp.335–341.

Birks, M., Chapman, Y. and Francis, K. (2008). Memoing in Qualitative Research. *Journal of Research in Nursing*, 13(1), pp.68–75.

Bittner, E.A.C. and Leimeister, J.M. (2013). Why Shared Understanding Matters -- Engineering a Collaboration Process for Shared Understanding to Improve Collaboration Effectiveness in Heterogeneous Teams. In: *2013 46th Hawaii International Conference on System Sciences*. [online] pp.106–114. Available at: http://pubs.wi-kassel.de/wp-content/uploads/2013/04/JML_387.pdf [Accessed 17 Jul. 2021].

Blackman, D., Kennedy, M. and Ritchie, B. (2011). Knowledge Management: The Missing Link in DMO Crisis Management? *Current Issues in Tourism*, 14(4), pp.337–354.

Blackman, K.C., Zoellner, J., Berrey, L.M., Alexander, R., Fanning, J., Hill, J.L. and Estabrooks, P.A. (2013). Assessing the Internal and External Validity of Mobile Health Physical Activity Promotion Interventions: A Systematic Literature Review Using the RE-AIM Framework. *Journal of Medical Internet Research*, 15(10), p.e224.

Blackwell, D.L. and Clarke, T.C. (2018). State Variation in Meeting the 2008 Federal Guidelines for Both Aerobic and Muscle-strengthening Activities Through Leisure-time Physical Activity Among Adults Aged 18-64: United States, 2010-2015. *National Health Statistics Reports*, 112(), pp.1–22.

Blagden, S., Austin, C., Richey, R. and Desai, M. (2021). NICE Public Health Guidance Update. *Journal of Public Health*, 43(1), pp.e107–e109.

Blandford, A. (2019a). Lessons from Working with Researchers and Practitioners in

Healthcare. *Interactions*, 26(1), pp.72–75.

Blandford, A. (2019b). HCI for Health and Wellbeing: Challenges and Opportunities. *International Journal of Human-Computer Studies*, 131, pp.41–51.

Blandford, A., Gibbs, J., Newhouse, N., Perski, O., Singh, A. and Murray, E. (2018). Seven Lessons for Interdisciplinary Rresearch on Interactive Digital Health Interventions. *Digital Health*, 4, pp.1–13.

Blanson Henkemans, O., Paradies, G., Neerincx, M., Looije, R. and van Emepelen, P. (2015). Lost in Persuasion A Multidisciplinary Approach for Developing Usable, Effective, and Reproducible Persuasive Technology for Health Promotion. In: *Proceedings of the 9th International Conference on Pervasive Computing Technologies for Healthcare*. [online] pp.49–56. Available at: https://ieeexplore.ieee.org/document/7349377 [Accessed 17 Jul. 2021].

Blavatsky, H.P. (1888). *The Secret Doctrine: The Synthesis of Science, Religion and Philosophy*. London: Theosophical Publishing Company.

Blaxter, M. (2010). *Health*. 2nd ed. Cambridge: Polity.

Bloom, D.E. (2013). *Economic Impact of Noncommunicable Disease in China and India: Estimates, Projections and Comparisons*. [online] Bangalore: Institute for Social and Economic Change. Available at: https://ideas.repec.org/p/sch/wpaper/300.html [Accessed 17 Jul. 2021].

Bloom, D.E., Cafiero, E.T., Jane-Llopis, E., Abrahams-Gessel, S., Bloom, L.R., Fathima, S., Feigl, A.B., Gaziano, T., Mowafi, M., Pandya, A., Prettner, K., Rosenberg, L., Seligman, B., Stein, A.Z. and Weinstein, C. (2011). *The Global Economic Burden of Noncommunicable Diseases*. Geneva: World Economic Forum.

Blumer, H. (1969). *Symbolic Interactionism: Perspective and Method*. Berkeley: University of California Press.

Boell, S.K. and Cecez-Kecmanovic, D. (2010). Literature Reviews and the Hermeneutic Circle. *Australian Academic & Research Libraries*, 41(2), pp.129–144.

Boell, S.K. and Cecez-Kecmanovic, D. (2014). A Hermeneutic Approach for Conducting

Literature Reviews and Literature Searches. *Communications of the Association for Information Systems*, 34, pp.257–286.

Bohlen, L.C., Michie, S., de Bruin, M., Rothman, A.J., Kelly, M.P., Groarke, H.N.K., Carey, R.N., Hale, J. and Johnston, M. (2020). Do Combinations of Behaviour Change Techniques That Occur Frequently in Interventions Reflect Underlying Theory? *Annals of Behavioural Medicine*, 54(11), pp.827–842.

Bondaronek, P., Alkhaldi, G., Slee, A., Hamilton, F.L. and Murray, E. (2018). Quality of Publicly Available Physical Activity Apps: Review and Content Analysis. *JMIR mHealth and uHealth*, 6(3), pp.1–16.

Botha, A. (2011). *A Framework to Enhance the Mobile User Experience in an MLearning Interaction*. PhD. Nelson Mandela University.

Boujut, J. and Blanco, E. (2003). Intermediary Objects as a Means to Foster Co-operation in Engineering Design. *Computer Supported Cooperative Work (CSCW)*, 12(2), pp.205–219.

Boulos, M.N. and Yang, S.P. (2021). Mobile Physical Activity Planning and Tracking: A Brief Overview of Current Options and Desiderata for Future Solutions. *mHealth*, 7, pp.13–13.

Boulton, E., Hawley-Hague, H., French, D.P., Mellone, S., Zacchi, A., Clemson, L., Vereijken, B. and Todd, C. (2019). Implementing Behaviour Change Theory and Techniques to Increase Physical Activity and Prevent Functional Decline Among Adults Aged 61-70: The PreventIT Project. *Progress in cardiovascular diseases*, 62(2), pp.147–156.

Bowker, G.C. and Star, S.L. (1999). *Sorting Things Out: Classification and its Consequences*. Cambridge: MIT Press.

Boyatzis, R.E. (1998). *Transforming Qualitative Information: Thematic Analysis and Code Development*. Thousand Oaks: Sage Publications.

Bradbury, K., Watts, S., Arden-Close, E., Yardley, L. and Lewith, G. (2014). Developing Digital Interventions: A Methodological Guide. *Evidence-Based Complementary and Alternative Medicine*, 2014, pp.1–7.

Bradway, M., Morris, R.L., Giordanengo, A. and Årsand, E. (2020). How mHealth Can Facilitate Collaboration in Diabetes Care: Qualitative Analysis of Co-Design Workshops. *BMC Health Services Research*, 20(1).

Braun, V. and Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, 3(2), pp.77–101.

Braun, V. and Clarke, V. (2012). Thematic Analysis. In: *APA Handbook of Research Methods in Psychology, Vol 2: Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological.* Washington, DC: American Psychological Association, pp.57–71.

Braun, V. and Clarke, V. (2019). Reflecting on Reflexive Thematic Analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4), pp.589–597.

Broberg, O. (2011). Enabling Objects for Participatory Design of Socio-Technical Systems. In: *International Conference on Engineering Design ICED11*. [online] Available at: https://www.semanticscholar.org/paper/Enabling-objects-for-participatory-design-of-Broberg/530654ada4cc327be8290bafb28f17f5e77dc2ba [Accessed 16 Jul. 2021].

Bronfenbrenner, U. (1977). Toward an Experimental Ecology of Human Development. *American Psychologist*, 32(7), pp.513–531.

Broniatowski, D.A. and Magee, C.L. (2018). The Emergence and Collapse of Knowledge Boundaries. *IEEE Transactions on Engineering Management*, 64(3), pp.337–350.

Brown, B., Crawford, P. and Darongkamas, J. (2000). Blurred Roles and Permeable Boundaries: The Experience of Multidisciplinary Working in Community Mental Health. *Health and Social Care in the Community*, 8(6), pp.425–435.

Brown, M.C., Araújo-Soares, V., Skinner, R., Glaser, A.W., Sarwar, N., Saxton, J.M., Montague, K., Hall, J., Burns, O. and Sharp, L. (2020). Using Qualitative and Co-Design Methods to Inform the Development of an Intervention to Support and Improve Physical Activity in Childhood Cancer Survivors: a Study Protocol for BEing Active after ChildhOod caNcer (BEACON). *BMJ Open*, 10(12), pp.1–11.

Brug, J., Oenema, A. and Ferreira, I. (2005). Theory, Evidence and Intervention Mapping to Improve Behaviour Nutrition and Physical Activity Interventions. *International Journal*

*of Behavioural Nutrition and Physical Activity*, 2(1), p.2.

Brug, J., van der Ploeg, H.P., Loyen, A., Ahrens, W., Allais, O., Andersen, L.F., Cardon, G., Capranica, L., Chastin, S., De Bourdeaudhuij, I., De Craemer, M., Donnelly, A., Ekelund, U., Finglas, P., Flechtner-Mors, M., Hebestreit, A., Kubiak, T., Lanza, M., Lien, N. and MacDonncha, C. (2017). Determinants of Diet and Physical Activity (DEDIPAC): A Summary of Findings. *The International Journal of Behavioural Nutrition and Physical Activity*, 14, pp.1–24.

Bryman, A. (2012a). *Social Research Methods*. 4th ed. New York: Oxford University Press.

Bryman, A. (2012b). *Social Research Methods*. 4th ed. Oxford: Oxford University Press.

Buchan, D.S., Ollis, S., Thomas, N.E. and Baker, J.S. (2012). Physical Activity Behaviour: An Overview of Current and Emergent Theoretical Practices. *Journal of Obesity*, 2012, pp.1–11.

Buckingham, S.A., Williams, A.J., Morrissey, K., Price, L. and Harrison, J. (2019). Mobile Health Interventions to Promote Physical Activity and Reduce Sedentary Behaviour in the Workplace: A Systematic Review. *Digital Health*, 5, pp.1–50.

Budreviciute, A., Damiati, S., Sabir, D.K., Onder, K., Schuller-Goetzburg, P., Plakys, G., Katileviciute, A., Khoja, S. and Kodzius, R. (2020). Management and Prevention Strategies for Non-communicable Diseases (NCDs) and Their Risk Factors. *Frontiers in Public Health*, 8, pp.1–11.

Bul, K., Holliday, N., Magee, P. and Wark, P. (2020). From Development to Exploitation of Digital Health Solutions: Lessons Learnt Through Multidisciplinary Research and Consultancy. *Journal of Enabling Technologies*, 14(4), pp.273–279.

Bull, F.C., Al-Ansari, S.S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P.C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C.M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P.T. and Lambert, E. (2020). World Health Organisation 2020 Guidelines on Physical Activity and Sedentary Behaviour. *British Journal of Sports Medicine*, 54(24), pp.1451–1462.

Bully, P., Sánchez, Á., Zabaleta-del-Olmo, E., Pombo, H. and Grandes, G. (2015). Evidence

from Interventions Based on Theoretical Models for Lifestyle Modification (Physical Activity, Diet, Alcohol and Tobacco Use) in Primary Care settings: A Systematic Review. *Preventive Medicine*, 76, pp.S76–S93.

Burke, S., Carron, A., Eys, M., Ntoumanis, N. and Estabrooks, P. (2006). Group versus Individual Approach? A Meta-Analysis of the Effectiveness of Interventions to Promote Physical Activity. *Sport and Exercise Psychology Review*, 2(1), pp.1–39.

Burrell, G. and Morgan, G. (1979). *Sociological Paradigms and Organisational Analysis: Elements of the Sociology of Corporate Life*. Burlington: Heinemann Educational Books.

Cabitza, F. (2015). At the Boundary of Communities and Roles: Boundary Objects and Knowledge Artifacts as Resources for IS Design. In: L. Mola, F. Pennarola and S. Za, eds., *From Information to Smart Society, Lecture Notes in Information Systems and Organisation*. Springer, pp.149–160.

Caccamo, M. (2020). *Cross-Boundary Knowledge Work in Innovation: Understanding the Role of Space and Objects*. PhD. Jönköping University.

Callahan, D. (1973). The WHO Definition of "Health." *Studies - Hastings Center*, 1(3), pp.77–88.

Callon, M. (1986). The Sociology of an Actor-Network: The Case of the Electric Vehicle. In: M. Callon, J. Law and A. Rip, eds., *Mapping the Dynamics of Science and Technology*. London: Macmillan Press, pp.19–34.

Cameron, J.D., Ramaprasad, A. and Syn, T. (2017). An Ontology of and Roadmap for mHealth Research. *International Journal of Medical Informatics*, 100, pp.16–25.

Campbell, P.L. (2011). *Peirce, Pragmatism, and the Right Way of Thinking*. [online] *Office of Scientific and Technical Information*. Available at: https://fas.org/sgp/eprint/peirce.pdf [Accessed 15 Jul. 2021].

Carey, R.N., Connell, L.E., Johnston, M., Rothman, A.J., de Bruin, M., Kelly, M.P. and Michie, S. (2019). Behaviour Change Techniques and Their Mechanisms of Action: A Synthesis of Links Described in Published Intervention Literature. *Annals of Behavioural Medicine*, 53(8), pp.693–707.

Carleheden, M. (2016). What Conception of the Theoretical Does "Theorising" Presuppose? Comment on Richard Swedberg's "Before Theory Comes Theorising or How to Make Social Science More Interesting." *The British Journal of Sociology*, 67(1), pp.36–42.

Carlile, P.R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organisation Science*, 13(4), pp.442–455.

Carlile, P.R. (2004). Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries. *Organisation Science*, 15(5), pp.555–568.

Carlile, P.R. (2006). Using Artifacts to Interpret and Negotiate Knowledge across Domains. [online] pp.1–26. Available at: https://www.researchgate.net/publication/255571335_Using_Artifacts_to_Interpret_and_Negotiate_Knowledge_across_Domains [Accessed 16 Jul. 2021].

Carlile, P.R. and Lakhani, K.R. (2011). Innovation and the Challenge of Novelty: The Novelty-Confirmation-Transformation Cycle in Software and Science. [online] pp.1–41. Available at: https://www.researchgate.net/publication/228197589_Innovation_and_the_Challenge_of_Novelty_The_Novelty-Confirmation-Transformation_Cycle_in_Software_and_Science [Accessed 17 Jul. 2021].

Carlile, P.R. and Rebentisch, E.S. (2003). Into the Black Box: The Knowledge Transformation Cycle. *Management Science*, 49(9), pp.1180–1195.

Carlile, P.R., Nicolini, D., Langley, A. and Tsoukas, H. (2013). *How Matter Matters: Objects, Artifacts, and Materiality in Organisation Studies*. Oxford: Oxford University Press.

Carlsson, S.A. (2011). Critical Realist Information Systems Research in Action. In: *IFIP Advances in Information and Communication Technology*. [online] pp.269–284. Available at: https://link.springer.com/chapter/10.1007/978-3-642-21364-9_17 [Accessed 15 Jul. 2021].

Carvalho, F., Jun, G.T. and Mitchell, V. (2017). Participatory Design for Behaviour Change: An Integrative Approach to Healthcare Quality Improvement. In: *IASDR 2017 Proceedings, 7th International Congress of the International Association of Societies of Design Research*. [online] pp.1–22. Available at:

https://scholar.uc.edu/concern/articles/2z10wq20d?locale=en [Accessed 17 Jul. 2021].

Cash, P., Dekoninck, E.A. and Ahmed-Kristensen, S. (2017). Supporting the Development of Shared Understanding in Distributed Design Teams. *Journal of Engineering Design*, 28(3), pp.147–170.

Caspersen, C.J., Powell, K.E. and Christenson, G.M. (1985). Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. *Public Health Reports*, 100(2), pp.126–131.

Cerbas, S., Kelemen, A., Liang, Y., Sik-Lanyi, C. and Van de Castle, B. (2021). A Physical Activity Mobile Game for Hematopoietic Stem Cell Transplant Patients: App Design, Development, and Evaluation. *JMIRx Med*, 2(2), pp.1–10.

Charlemagne-Badal, S.J., Lee, J.W., Butler, T.L. and Fraser, G.E. (2015). Conceptual Domains Included in Wellbeing and Life Satisfaction Instruments: A Review. *Applied Research in Quality of Life*, 10(2), pp.305–328.

Chasanidou, D. (2018). Design for Motivation: Evaluation of a Design Tool. *Multimodal Technologies and Interaction*, 2(1), p.6.

Chatterjee, A., Gerdes, M., Prinz, A. and Martinez, S. (2021). Realising the Effectiveness of Digital Interventions on Sedentary Behaviour (Physical Inactivity, Unhealthy Habit, Improper Diet) Monitoring and Prevention Approaches as a Meta-Analysis. [Preprint] Available from: https://preprints.jmir.org/preprint/26931. [Accessed 16 July 2021].

Checkland, P. (2000). Soft Systems Methodology: A Thirty Year Retrospective. *Systems Research and Behavioural Science Syst. Res.*, 17(S1), pp.S11–S58.

Chen, K. (2019). The Value of a Systemic Design Approach. *The BHW Group*. Available at: https://thebhwgroup.com/blog/the-value-of-a-systemic-design-approach [Accessed 17 Jul. 2021].

Chew, H.S.J., Ang, W.H.D. and Lau, Y. (2021). The Potential of Artificial Intelligence in Enhancing Adult Weight Loss: A Scoping Review. *Public Health Nutrition*, [online] pp.1–28. Available at: https://pubmed.ncbi.nlm.nih.gov/33592164/ [Accessed 17 Jul. 2021].

Chiu, J.L. and Linn, M.C. (2011). Knowledge Integration and Wise Engineering. *Journal of Pre-College Engineering Education Research (J-PEER)*, 1(1).

Chiu, W., Cho, H. and Chi, C.G. (2020). Consumers' Continuance Intention to Use Fitness and Health Apps: An Integration of the Expectation – Confirmation Model and Investment Model. *Information Technology & People*, 34(3).

Choi, B.C.K. and Pak, A.W.P. (2006). Multidisciplinarity, Interdisciplinarity and Transdisciplinarity in Health Research, Services, Education and Policy: 1. Definitions, Objectives, and Evidence of Effectiveness. *Clinical and Investigative Medicine. Medecine Clinique Et Experimentale*, 29(6), pp.351–364.

Choi, J., Lee, M., Lee, J., Kang, D. and Choi, J.-Y. (2017). Correlates Associated with Participation in Physical Activity Among Adults: A Systematic Review of Reviews and Update. *BMC Public Health*, 17(1), pp.356–369.

Chow, P.I. (2020). Developing Mental or Behavioural Health Mobile Apps for Pilot Studies by Leveraging Survey Platforms: A Do-it-Yourself Process. *JMIR mHealth and uHealth*, 8(4), p.e15561.

Christiansen, E.T. (2005). Boundary Objects, Please Rise! On the Role of Boundary Objects in Distributed Collaboration and How to Design for Them. [online] Available at: https://vbn.aau.dk/en/publications/boundary-objects-please-rise-on-the-role-of-boundary-objects-in-d [Accessed 16 Jul. 2021].

Christopher, H., Zwickl, P., Hlavacs, H. and Reichl, P. (2015). Towards a Framework for Gamification-Based Intervention Mapping in mHealth. In: *Entertainment Computing - ICEC 2015*. pp.508–513.

Clarke, D., Hawkins, R., Euan Sadler, Harding, G., Forster, A., McKevitt, C., Godfrey, M., Monaghan, J., Am and a Farrin (2012). Interdisciplinary Health Research: Perspectives from a Process Evaluation Research Team. *Quality in Primary Care*, 20(3), pp.179–189.

Cole, R., Purao, S., Rossi, M. and Sein, M. (2005). Being Proactive: Where Action Research Meets Design Research. *ICIS 2005 Proceedings*, [online] Available at: https://aisel.aisnet.org/icis2005/27/ [Accessed 15 Jul. 2021].

Collins, C.S. and Stockton, C.M. (2018). The Central Role of Theory in Qualitative Research. *International Journal of Qualitative Methods*, 17(1), pp.1–10.

Collins, L.M. (2018). *Optimisation of Behavioural, Biobehavioural and Biomedical Interventions: The Multiphase Optimisation Strategy (MOST)*. London: Springer International Publishing.

Collins, L.M., Murphy, S.A. and Strecher, V. (2007). The Multiphase Optimization Strategy (MOST) and the Sequential Multiple Assignment Randomised Trial (SMART). *American Journal of Preventive Medicine*, 32(5), pp.S112–S118.

Collins, L.M., Murphy, S.A., Nair, V.N. and Strecher, V.J. (2005). A Strategy for Optimizing and Evaluating Behavioural Interventions. *Annals of Behavioural Medicine*, 30(1), pp.65–73.

Condello, G., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Simon, C., Ciarapica, D., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P., Jaeschke, L. and Kanning, M. (2017). Behavioural Determinants of Physical Activity Across the Life Course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) Umbrella Systematic Literature Review. *International Journal of Behavioural Nutrition and Physical Activity*, 14(1).

Conner, M. and Norman, P. (2017). Health behaviour: Current Issues and Challenges. *Psychology & Health*, 32(8), pp.895–906.

Conroy, D.E., Yang, C.H. and Maher, J.P. (2014). Behaviour Change Techniques in Top-Ranked Mobile Apps for Physical Activity. *American Journal of Preventive Medicine*, 46(6), pp.649–652.

Consolvo, S., Klasnja, P., McDonald, D.W., Avrahami, D., Froehlich, J., LeGrand, L., Libby, R., Mosher, K. and Landay, J.A. (2008). Flowers or a Robot Army? Encouraging Awareness & Activity with Personal Mobile Displays. In: *Proceedings of the 10th international conference on Ubiquitous computing - UbiComp '08*. [online] Available at: https://dl.acm.org/doi/10.1145/1409635.1409644 [Accessed 16 Jul. 2021].

Corbin, J. and Strauss, A. (2015). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. 4th ed. Thousand Oaks: Sage Publications.

Cortis, C., Puggina, A., Pesce, C., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Simon, C., Ciarapica, D., Condello, G., Coppinger, T., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P. and Jaeschke, L. (2017). Psychological Determinants of Physical Activity Across the Life Course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) Umbrella Systematic Literature Review. *PLOS ONE*, 12(8), p.e0182709.

Cotton, V. and Patel, M.S. (2019). Gamification Use and Design in Popular Health and Fitness Mobile Applications. *American Journal of Health Promotion*, 33(3), pp.448–451.

Coughlin, S.S., Whitehead, M., Sheats, J.Q., Mastromonico, J. and Smith, S. (2016). A Review of Smartphone Applications for Promoting Physical Activity. *Jacobs Journal of Community Medicine*, 2(1).

Covolo, L., Ceretti, E., Moneda, M., Castaldi, S. and Gelatti, U. (2017). Does Evidence Support the Use of Mobile Phone Apps as a Driver for Promoting Healthy Lifestyles from a Public Health Perspective? A Systematic Review of Randomised Control Trials. *Patient Education and Counseling*, 100(12), pp.2231–2243.

Cowan, L.T., Van Wagenen, S.A., Brown, B.A., Hedin, R.J., Seino-Stephan, Y., Hall, P.C. and West, J.H. (2012). Apps of Steel: Are Exercise Apps Providing Consumers With Realistic Expectations? *Health Education & Behaviour*, 40(2), pp.133–139.

Crabtree, B. and Miller, W. (1992). A Template Approach to Text Analysis: Developing and Using Codebooks. In: B. Crabtree and W. Miller, eds., *Doing Qualitative Research in Primary Care: Multiple Strategies*. Newbury Park, CA: Sage Publications, pp.93–109.

Crabtree, B.F. and Miller, W.L. (1999). *Doing Qualitative Research*. 2nd ed. Thousand Oaks: Sage Publications.

Craggs, C., Corder, K., van Sluijs, E.M.F. and Griffin, S.J. (2011). Determinants of Change in Physical Activity in Children and Adolescents. *American Journal of Preventive Medicine*, 40(6), pp.645–658.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. and Petticrew, M. (2008). Developing and Evaluating Complex Interventions: The New Medical Research Council Guidance. *BMJ*, 337, pp.1–39.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. and Petticrew, M. (2013). Developing and Evaluating Complex Interventions: The New Medical Research Council Guidance. *International Journal of Nursing Studies*, 50(5), pp.587–592.

Creswell, J.W. (2013). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. 3rd ed. London: Sage Publications.

Creswell, J.W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Thousand Oaks: Sage Publications.

Creswell, J.W. and Miller, D.L. (2000). Determining Validity in Qualitative Inquiry. *Theory into Practice*, 39(3), pp.124–130.

Cruse, D. (2000). *Meaning in Language: An Introduction to Semantics and Pragmatics*. New York: Oxford University Press.

Crutzen, R. (2014). The Behavioural Intervention Technology Model and Intervention Mapping: The Best of Both Worlds. *Journal of Medical Internet Research*, 16(8), pp.1–2.

Curtis, K.E., Lahiri, S. and Brown, K.E. (2015). Targeting Parents for Childhood Weight Management: Development of a Theory-Driven and User-Centered Healthy Eating App. *JMIR mHealth and uHealth*, 3(2), pp.1–18.

Dallinga, J.M., Mennes, M., Alpay, L., Bijwaard, H. and Baart de la Faille-Deutekom, M. (2015). App Use, Physical Activity and Healthy Lifestyle: A Cross Sectional Study. *BMC Public Health*, 15(1).

Dam, R.F. and Siang, T.Y. (2020). *Design Thinking: A Quick Overview*. [online] The Interaction Design Foundation. Available at: https://www.interaction-design.org/literature/article/design-thinking-a-quick-overview [Accessed 17 Jul. 2021].

Damen, I., Brombacher, H., Lallemand, C., Brankaert, R., Brombacher, A., van Wesemael, P. and Vos, S. (2020). A Scoping Review of Digital Tools to Reduce Sedentary Behaviour or Increase Physical Activity in Knowledge Workers. *International Journal of Environmental Research and Public Health*, 17(2), p.499.

Damtew, Z.A. (2013). *Harnessing Community Knowledge for Health: Case Studies from*

*Community Health Service and Information Systems in Ethiopia*. PhD. University of Oulu.

Das, P. and Horton, R. (2016). Physical Activity— Time to Take it Seriously and Regularly. *The Lancet*, 388(10051), pp.1254–1255.

Davies, A. and Mueller, J. (2020). *Developing Medical Apps and mHealth Interventions: A Guide for Researchers, Physicians and Informaticians*. Switzerland: Springer Nature.

Davis, G.B. (2005). Advising and Supervising. In: D. Avison and J. Pries-Heje, eds., *Research in Information Systems: A Handbook for Research Supervisors and Their Students*. Oxford: Elsevier Butterworth-Heinemann, pp.3–33.

Davis, R., Campbell, R., Hildon, Z., Hobbs, L. and Michie, S. (2015). Theories of Behaviour and Behaviour Change Across the Social and Behavioural Sciences: A Scoping Review. *Health Psychology Review*, 9(3), pp.323–344.

De Chavez, A.C., Backett-Milburn, K., Parry, O. and Platt, S. (2005). Understanding and Researching Wellbeing: Its Usage in Different Disciplines and Potential for Health Research and Health Promotion. *Health Education Journal*, 64(1), pp.70–87.

De Cocker, K. (2020). Digital Health Interventions in Everyday Settings. *International Journal of Environmental Research and Public Health*, 17(8), pp.2702–2703.

De Ridder, D., Kroese, F., Evers, C., Adriaanse, M. and Gillebaart, M. (2017). Healthy Diet: Health Impact, Prevalence, Correlates, and Interventions. *Psychology & Health*, 32(8), pp.907–941.

Deci, E.L. and Ryan, R.M. (1985). *Intrinsic Motivation and Self-Determination in Human Behaviour*. New York: Plenum.

Deci, E.L. and Ryan, R.M. (2008). Self-Determination Theory: A Macrotheory of Human Motivation, Development, and Health. *Canadian Psychology/Psychologie Canadienne*, 49(3), pp.182–185.

DeFilippis, E., Impink, S., Singell, M., Polzer, J.T. and Sadun, R. (2020). Collaborating During Coronavirus: The Impact of COVID-19 on the Nature of Work. *SSRN Electronic Journal*. [online] Available at: https://www.nber.org/papers/w27612 [Accessed 17 Jul. 2021].

Defo, B.K. (2014). Beyond the “Tansition” Frameworks: The Cross-Continuum of Health, Disease and Mortality Framework. *Global Health Action*, 7(1), pp.1–16.

Degroote, L., Van Dyck, D., De Bourdeaudhuij, I., De Paepe, A. and Crombez, G. (2020). Acceptability and Feasibility of the mHealth Intervention “MyDayPlan” to Increase Physical Activity in a General Adult Population. *BMC Public Health*, 20(1).

Demiris, G. (2012). New Era for the Consumer Health Informatics Research Agenda. *Health Systems*, 1(1), pp.13–16.

Demiris, G. (2016). Consumer Health Informatics: Past, Present, and Future of a Rapidly Evolving Domain. *Yearbook of Medical Informatics*, 25(S1), pp.S42–S47.

Dempsey, P.C., Biddle, S.J.H., Buman, M.P., Chastin, S., Ekelund, U., Friedenreich, C.M., Katzmarzyk, P.T., Leitzmann, M.F., Stamatakis, E., van der Ploeg, H.P., Willumsen, J. and Bull, F. (2020). New Global Guidelines on Sedentary Behaviour and Health for Adults: Broadening the Behavioural Targets. *International Journal of Behavioural Nutrition and Physical Activity*, 17(1), pp.151–162.

Deng, Q. and Ji, S. (2018). A Review of Design Science Research in Information Systems: Concept, Process, Outcome, and Evaluation. *Pacific Asia Journal of the Association for Information Systems*, 10(1), pp.1–36.

Department of Health (2015). *mHealth Strategy 2015-2019*. [online] Health Systems Trust. Available at: https://www.hst.org.za/publications/NonHST%20Publications/mHealth%20Strategy%202015.pdf#search=MHEALTH [Accessed 16 Jul. 2021].

DeSmet, A., De Bourdeaudhuij, I., Chastin, S., Crombez, G., Maddison, R. and Cardon, G. (2019). Adults’ Preferences for Behaviour Change Techniques and Engagement Features in a Mobile App to Promote 24-Hour Movement Behaviours: Cross-Sectional Survey Study. *JMIR mHealth and uHealth*, 7(12), p.e15707.

DeSmet, A., Thompson, D., Baranowski, T., Palmeira, A., Verloigne, M. and De Bourdeaudhuij, I. (2016). Is Participatory Design Associated with the Effectiveness of Serious Digital Games for Healthy Lifestyle Promotion? A Meta-Analysis. *Journal of Medical Internet Research*, 18(4), p.e94.

Dewey, J. (1910). *How We Think*. Boston: D.C. Heath & Co.

Dewey, J. (1931). *Philosophy and Civilization*. New York: Minton, Balch & Company.

Dhiman, N., Arora, N., Dogra, N. and Gupta, A. (2020). Consumer adoption of smartphone fitness apps: an extended UTAUT2 perspective. *Journal of Indian Business Research*, 12(3), pp.363–388.

Di Geronimo, L., Braz, L., Fregnan, E., Palomba, F. and Bacchelli, A. (2020). UI Dark Patterns and Where to Find Them. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. [online] Available at: https://dl.acm.org/doi/10.1145/3313831.3376600 [Accessed 17 Jul. 2021].

Dibiaggio, L. (2007). Design Complexity, Vertical Disintegration and Knowledge Organisation in the Semiconductor Industry. *Industrial and Corporate Change*, 16(2), pp.239–267.

Dick, S., O'Connor, Y. and Heavin, C. (2017). A Comparison of Mobile Health Evaluation Techniques. In: *AMCIS 2017 Proceedings*. [online] pp.1–9. Available at: https://aisel.aisnet.org/amcis2017/ICTs/Presentations/4/ [Accessed 16 Jul. 2021].

Ding, D. (2018). Surveillance of Global Physical Activity: Progress, Evidence, and Future Directions. *The Lancet Global Health*, 6(10), pp.e1046–e1047.

Ding, D., Lawson, K.D., Kolbe-Alexander, T.L., Finkelstein, E.A., Katzmarzyk, P.T., van Mechelen, W. and Pratt, M. (2016). The Economic Burden of Physical Inactivity: A Global Analysis of Major Noncommunicable Diseases. *The Lancet*, 388(10051), pp.1311–1324.

Dirckinck-Holmfeld, L. (2006). Designing for Collaboration and Mutual Negotiation of Meaning - Boundary Objects in Networked Learning. In: *Fifth International Conference on Networked Learning 2006*. [online] pp.8 pages. Available at: https://telearn.archives-ouvertes.fr/hal-00190304 [Accessed 17 Jul. 2021].

Direito, A., Carraça, E., Rawstorn, J., Whittaker, R. and Maddison, R. (2017). mHealth Technologies to Influence Physical Activity and Sedentary Behaviours: Behaviour Change Techniques, Systematic Review and Meta-Analysis of Randomised Controlled

Trials. *Annals of Behavioural Medicine*, 51(2), pp.226–239.

Direito, A., Jiang, Y., Whittaker, R. and Maddison, R. (2015). Smartphone Apps to Improve Fitness and Increase Physical Activity Among Young People: Protocol of the Apps for IMproving FITness (AIMFIT) Randomised Controlled Trial. *BMC Public Health*, 15(1).

Direito, A., Walsh, D., Hinbarji, M., Albatal, R., Tooley, M., Whittaker, R. and Maddison, R. (2018). Using the Intervention Mapping and Behavioural Intervention Technology Frameworks: Development of an mHealth Intervention for Physical Activity and Sedentary Behaviour Change. *Health Education & Behaviour*, 45(3), pp.331–348.

Dishman, R.K., Sallis, J.F. and Orenstein, D.R. (1985). The Determinants of Physical Activity and Exercise. *Public Health Rep*, 100(2), pp.158–171.

Dodds, S. and Hess, A.C. (2021). Adapting Research Methodology During COVID-19: Lessons for Transformative Service Research. *Journal of Service Management*, 32(2).

Dogra, S. and Stathokostas, L. (2012). Sedentary Behaviour and Physical Activity Are Independent Predictors of Successful Aging in Middle-Aged and Older Adults. *Journal of Aging Research*, 2012, pp.1–8.

Donev, D., Pavlekovic, G. and Kragelj, L.Z. (2008). Social Networks and Social Support in Health Promotion Programmes. In: E.J. Eckenfels, ed., *Programmes for Training on Research in Public Health for South Eastern Europe. Vol. 4: Health promotion and disease prevention: A Handbook for Teachers, Researchers, Health Professionals and Decision Makers*. Universitätsbibliothek Bielefeld.

Doolin, B. and McLeod, L. (2012). Sociomateriality and Boundary Objects in Information Systems Development. *European Journal of Information Systems*, 21(5), pp.570–586.

Dörendahl, E.I. (2015). *Boundary Work for Collaborative Water Resources Management*. PhD. Westfälischen Wilhelms-Universität Münster.

Dougherty, D. (1992). Interpretive Barriers to Successful Product Innovation in Large Firms. *Organisation Science*, 3(2), pp.179–202.

Du Plessis, L. and de Vries, M. (2016). Towards a Holistic Customer Eexperience Managment Framework for Enterprises. *South African Journal of Industrial Engineering*, 27(3),

pp.23–36.

Dugas, M., Gao, G. (Gordon) and Agarwal, R. (2020). Unpacking mHealth Interventions: A Systematic Review of Behaviour change Techniques used in Randomised Controlled Trials Assessing mHealth Effectiveness. *Digital Health*, 6, pp.1–16.

Duncan, M., Murawski, B., Short, C.E., Rebar, A.L., Schoeppe, S., Alley, S., Vandelanotte, C. and Kirwan, M. (2017). Activity Trackers Implement Different Behaviour Change Techniques for Activity, Sleep, and Sedentary Behaviours. *Interactive Journal of Medical Research*, 6(2), p.e13.

Dupont, L., Gholipour, V., Morel, L., Bignon, J.C. and Guidat, C. (2012). From Urban Concept to Urban Engineering: The Contribution of Distributed Collaborative Design to the Management of Urban Projects. *Journal of Urban Design*, 17(2), pp.255–277.

Eckerstorfer, L.V., Tanzer, N.K., Vogrincic-Haselbacher, C., Kedia, G., Brohmer, H., Dinslaken, I. and Corcoran, K. (2018). Key Elements of mHealth Interventions to Successfully Increase Physical Activity: Meta-Regression. *JMIR mHealth and uHealth*, 6(11), p.e10076.

Edenius, M., Keller, C. and Lindblad, S. (2010). Managing knowledge across boundaries in healthcare when innovation is desired. *Knowledge Management & E-Learning: An International Journal*, 2(2), pp.134–153.

Edmunds, M., Hass, C. and Holve, E. (2019). *Consumer Informatics and Digital Health: Solutions for Health and Health Care*. Switzerland: Springer International Publishing.

Edwards, E.A., Caton, H., Lumsden, J., Rivas, C., Steed, L., Pirunsarn, Y., Jumbe, S., Newby, C., Shenvi, A., Mazumdar, S., Smith, J., Greenhill, D., Griffiths, C. and Walton, R. (2018). Creating a Theoretically Grounded, Gamified Health App: Lessons from Developing the Cigbreak Smoking Cessation Mobile Phone Game. *JMIR Serious Games*, 6(4), pp.1–20.

Edwards, E.A., Lumsden, J., Rivas, C., Steed, L., Edwards, L.A., Thiyagarajan, A., Sohanpal, R., Caton, H., Griffiths, C.J., Munafò, M.R., Taylor, S. and Walton, R.T. (2016). Gamification for Health Promotion: Systematic Review of Behaviour Change Techniques in Smartphone Apps. *BMJ Open*, 6(10), pp.1–10.

Egger, G. and Dixon, J. (2014). Beyond Obesity and Lifestyle: A Review of 21st Century Chronic Disease Determinants. *BioMed Research International*, 2014, pp.1–12.

Elder, J.P., Ayala, G.X. and Harris, S. (1999). Theories and Intervention Approaches to Health Behaviour Change in Primary Care. *American Journal of Preventive Medicine*, 17(4), pp.275–284.

Elueze, I.N. (2015). Evaluating the Effectiveness of Knowledge Brokering in Health Research: A Systematised Review with Some Bibliometric Information. *Health Information & Libraries Journal*, 32(3), pp.168–181.

Enberg, C. (2007). *Knowledge Integration in Product Development Projects*. PhD. Linköping University.

Engeström, Y. and Blackler, F. (2005). On the Life of the Object. *Organisation*, 12(3), pp.307–330.

Engeström, Y., Engeström, R. and Kärkkäinen, M. (1995). Polycontextuality and Boundary Crossing in Expert Cognition: Learning and Problem Solving in Complex Work Activities. *Learning and Instruction*, 5(4), pp.319–336.

Eriksson, J. (2008). *Supporting the Cooperative Design Process of End-User Tailoring*. PhD. Blekinge Institute of Technology.

Esparza, R. (2006). *Breaking Character for the First Time in His Life*. [online] *The New York Times*. 26 Nov. Available at: https://www.nytimes.com/2006/11/26/theater/26wadl.html [Accessed 15 Jul. 2021].

European Commission (2014). *Green Paper on Mobile Health ("mHealth")*. [online] European Commission. Available at: https://digital-strategy.ec.europa.eu/en/library/green-paper-mobile-health-mhealth [Accessed 16 Jul. 2021].

European Commission (2021). *What is Horizon 2020?* [online] European Commission. Available at: https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020 [Accessed 17 Jul. 2021].

Eysenbach, G. (2000). Recent Advances: Consumer Health Informatics. *BMJ*, 320(7251),

pp.1713–1716.

Eysenbach, G. (2011). CONSORT-EHEALTH: Improving and Standardizing Evaluation Reports of Web-based and Mobile Health Interventions. *Journal of Medical Internet Research*, 13(4), p.e126.

Fadhil, A. and Wang, Y. (2019). Patterns in eHealth Coaching Approaches Based on Persuasive Technology: A Systematic Review. [online] pp.1–16. Available at: https://www.researchgate.net/publication/334330822_Patterns_in_eHealth_Coaching_Approaches_Based_on_Persuasive_Technology_A_Systematic_Review?channel=doi&linkId=5d24f5e292851cf44074c85d&showFulltext=true [Accessed 16 Jul. 2021].

Faiola, A. and Holden, R.J. (2017). Consumer Health Informatics: Empowering Healthy-Living-Seekers Through mHealth. *Progress in Cardiovascular Diseases*, 59(5), pp.479–486.

Fanfarelli, J., Vie, S. and McDaniel, R. (2015). Understanding Digital Badges Through Feedback, Reward, and Narrative. *Communication Design Quarterly Review*, 3(3), pp.56–60.

Fanning, J. (2016). *A Social Cognitive Smartphone Application for Improving Physical Activity in Adults*. PhD. University of Illinois.

Feldhoff, B., Stockmann, N., Fanderl, N., Gahle, A., Graf, A., Leger, M. and Sonnberger, M. (2019). Bridging Theories and Practices: Boundary Objects and Constellation Analysis as Vehicles for Interdisciplinary Knowledge Integration. *Sustainability*, 11(19), pp.1–18.

Fendt, J. and Kaminska-Labbé, R. (2011). Relevance and Creativity Through Design-Driven Action Research: Introducing Pragmatic Adequacy. *European Management Journal*, 29(3), pp.217–233.

Fereday, J. and Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), pp.80–92.

Fereday, J. and Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development.

*International Journal of Qualitative Methods*, 5(1), pp.80–92.

Ferguson, D.B. (2018). *Transdisciplinary Climate Research to Support Decision Making*. PhD. University of Arizona.

Ferguson, T. (1995). Consumer health informatics. *The Healthcare Forum Journal*, 38(1), pp.28–33.

Fiedler, J., Eckert, T., Wunsch, K. and Woll, A. (2020). Key Facets to Build Up eHealth and mHealth Interventions to Enhance Physical Activity, Sedentary Behaviour and Nutrition in Healthy Subjects – An Umbrella Review. *BMC Public Health*, 20(1), pp.1–21.

Filip, D. (2016). *How Do SMEs Collaborate with Academia?* PhD. Aalborg Universitet.

Fischer, C., Gregor, S. and Aier, S. (2012). Forms of Discovery for Design Knowledge. In: *ECIS 2012 Proceedings*. [online] pp.1–12. Available at: https://aisel.aisnet.org/ecis2012/64/ [Accessed 15 Jul. 2021].

Fischer, C., Gregor, S. and Aier, S. (2012). Forms of Discovery for Design Knowledge. In: *ECIS 2012 Proceedings*. [online] pp.1–13. Available at: http://aisel.aisnet.org/ecis2012 [Accessed 17 Jul. 2021].

Fischer, G., Giaccardi, E., Eden, H., Sugimoto, M. and Ye, Y. (2005). Beyond Binary Choices: Integrating Individual and Social Creativity. *International Journal of Human-Computer Studies*, 63(4-5), pp.482–512.

Fischer, T., Reinhardt, G., Stumpf, P., Schwarz, P.E.H. and Harst, L. (2019). Think-Aloud Usability Testing of an App to Increase Physical Activity. [online] pp.1–26. Available at: https://www.researchgate.net/publication/340186352_Think-aloud_usability_testing_of_an_app_to_increase_physical_activity [Accessed 16 Jul. 2021].

Fishbein, M. and Ajzen, I. (1975). *Belief, Attitude, Intention, and Behaviour: An Introduction to Theory and Research*. Reading, MA: Addison-Wesley.

Fishbein, M. and Yzer, M.C. (2003). Using Theory to Design Effective Health Behaviour Interventions. *Communication Theory*, 13(2), pp.164–183.

Flaherty, D., Hoffman-Goetz, L. and Arocha, J.F. (2014). What is Consumer Health Informatics? A Systematic Review of Published Definitions. *Informatics for Health and Social Care*, 40(2), pp.91–112.

Fletcher, G.F., Balady, G., Blair, S.N., Blumenthal, J., Caspersen, C., Chaitman, B., Epstein, S., Froelicher, E.S.S., Froelicher, V.F., Pina, I.L. and Pollock, M.L. (1996). Statement on Exercise: Benefits and Recommendations for Physical Activity Programs for All Americans. *Circulation*, 94(4), pp.857–862.

Fominykh, M., Prasolova-Førland, E., Divitini, M. and Petersen, S.A. (2015). Boundary Objects in Collaborative Work and Learning. *Information Systems Frontiers*, 18(1), pp.85–102.

Fong, A., Valerdi, R. and Srinivasan, J. (2007). Boundary Objects as a Framework to Understand the Role of Systems Integrators. *Systems Research Forum*, 02(01), pp.11–18.

Ford, K.L. (2020). *An Exploration of Digital Health Academic-Industry Collaboration*. PhD. University of Colorado Denver.

Ford, K.L., Moore, S.L., Zhou, S., Gore, M.O., Portz, J., Zhang, X., Zane, R., Wiler, J. and Bull, S. (2019). Advancing Evidence-Based Digital Health Through an Innovative Research Environment: An Academic-Industry Collaboration Case Report. *mHealth*, 5(37), pp.1–8.

Ford, K.L., Portz, J.D., Zhou, S., Gornail, S., Moore, S.L., Zhang, X. and Bull, S. (2021). Benefits, Facilitators, and Recommendations for Digital Health Academic-Industry Collaboration: A Mini Review. *Frontiers in Digital Health*, 3.

Fox, N.J. (2011). Boundary Objects, Social Meanings and the Success of New Technologies. *Sociology*, 45(1), pp.70–85.

Francis, P. (2017). *Mobile App Development Process*. [online] The BHW Group. Available at: https://thebhwgroup.com/blog/mobile-app-development-process [Accessed 17 Jul. 2021].

Francisco, R. and da Costa Zanela Klein, A. (2020). Understanding Collaborative Problem-

Solving on the Move: A Design Science Research Journey. *BAR - Brazilian Administration Review*, 17(1).

Frank, S.R. (2000). Digital Health Care - The Convergence of Health Care and the Internet. *Journal of Ambulatory Care Management*, 23(2), pp.8–17.

French, C.E. (2016). *Bench to Bedside? Boundary Spanning in Academic Health Sciences Centres*. PhD. University of College London.

French, D.P., Olander, E.K., Chisholm, A. and Mc Sharry, J. (2014). Which Behaviour Change Techniques are Most Effective at Increasing Older Adults' Self-Efficacy and Physical Activity Behaviour? A Systematic Review. *Annals of Behavioural Medicine: A Publication of the Society of Behavioural Medicine*, 48(2), pp.225–34.

Fujiki, Y., Kazakos, K., Puri, C., Buddharaju, P., Pavlidis, I. and Levine, J. (2008). NEAT-o-Games. *Computers in Entertainment*, 6(2), p.1.

Fulton, E., Kwah, K., Wild, S. and Brown, K. (2018). Lost in Translation: Transforming Behaviour Change Techniques into Engaging Digital Content and Design for the StopApp. *Healthcare*, 6(3), pp.75–89.

Gabriel, K.K.P., Morrow, J.R. and Woolsey, A.T. (2012). Framework for Physical Activity as a Complex and Multidimensional Behaviour. *Journal of Physical Activity and Health*, 9(S1), pp.S11–S18.

Galletta, A. (2013). *Mastering the Semi-Structured Interview and Beyond: From Research Design to Analysis and Publication*. New York: New York University Press.

Ganter, J.H. (2011). Collaborative Situation Awareness: How a Cross-Cultural Chat Room Encourages Intelligence Sharing During Counterproliferation Operations. *SSRN Electronic Journal*, [online] 2011, pp.1–11. Available at: https://www.researchgate.net/publication/256008248_Collaborative_Situation_Awareness_How_a_Cross-Cultural_Chat_Room_Encourages_Intelligence_Sharing_During_Counterproliferation_Operations [Accessed 17 Jul. 2021].

Gao, Z. and Lee, J.E. (2019). Emerging Technology in Promoting Physical Activity and Health:

Challenges and Opportunities. *Journal of Clinical Medicine*, 8(11), pp.1830–1844.

Garrety, K. and Badham, R. (2001). The Politics of Socio-Technical Intervention: An Interactionist View. *Technology Analysis & Strategic Management*, 12(1), pp.103–118.

Garro-Abarca, V., Palos-Sanchez, P. and Aguayo-Camacho, M. (2021). Virtual Teams in Times of Pandemic: Factors That Influence Performance. *Frontiers in Psychology*, 12.

Gaskin, J., Thummadi, V., Lyytinen, K. and Yoo, Y. (2011). Digital Technology and the Variation in Design Routines: A Sequence Analysis of Four Design Processes. In: *Thirty Second International Conference on Information Systems, Shanghai 2011*. [online] pp.1–16. Available at: https://aisel.aisnet.org/icis2011/proceedings/organization/14/ [Accessed 17 Jul. 2021].

Gasson, S. (2005). The Dynamics of Sensemaking, Knowledge, and Expertise in Collaborative, Boundary-Spanning Design. *Journal of Computer-Mediated Communication*, 10(4), pp.1–33.

Gasson, S. (2013). Framing Wicked Problems in Enterprise-Systems Innovation Project Groups. In: J. Langan-Fox and C.L. Cooper, eds., *Boundary-Spanning in Organisations: Network, Influence and Conflict*. New York: Routledge, Taylor and Francis.

Gerber, A., Kotze, P. and Van der Merwe, A. (2015). Design Science Research as Research Approach in Doctoral Studies. In: *AMCIS 2015 Proceedings*. [online] Available at: https://aisel.aisnet.org/amcis2015/DSR/GeneralPresentations/3/ [Accessed 17 Jul. 2021].

Gerdes, J., Goei, S.L., Huizinga, M. and de Ruyter, D. (2020). Analytic Framework for Interdisciplinary Collaboration in Inclusive Education. *Journal of Workplace Learning*, 32(5), pp.377–388.

Gerling, C., Bosch-Herterich, A., de Paula, D., Haskamp, T. and Uebernickel, F. (2020). Exploring Boundary Objects and their Affordances in the Context of Design Thinking Projects from a Multi-Stakeholder Perspective. In: *Innovation and Product Development Management Conference*. [online] Available at: https://www.alexandria.unisg.ch/publications/260463 [Accessed 17 Jul. 2021].

Geuens, J., D'haeseleer, I., Geurts, L. and Vanden Abeele, V. (2016). Lenses of Motivational Design for mHealth. In: *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*. [online] pp.165–171. Available at: https://dl.acm.org/doi/10.1145/2968120.2987722 [Accessed 16 Jul. 2021].

Geuens, J., Geurts, L., Gerling, K., De Croon, R. and Vanden Abeele, V. (2019). Dyadic Lenses for the Motivational Design of mHealth: Bridging the Gap between Health Theory and App Design. In: *Proceedings of the 2019 International Conference on Healthcare Informatics*. pp.350–361.

Geuens, J., Geurts, L., Swinnen, T.W., Westhovens, R. and Vanden Abeele, V. (2019). *Lenses of Motivational Design*. [online] Lens of Motivational Design for mHeatlh. Available at: https://www.lensesofmotivationaldesign.com/ [Accessed 17 Jul. 2021].

Gibbons, M.C., Wilson, R.F., Samal, L., Lehman, C.U., Dickersin, K., Lehmann, H.P., Aboumatar, H., Finkelstein, J., Shelton, E., Sharma, R. and Bass, E.B. (2009). *Impact of Consumer Health Informatics Applications*. [online] Rockville: Agency of Healthcare Research and Quality, pp.1–546.

Gillham, B. (2000). *The Research Interview*. New York: Continuum.

Giunti, G. (2018). 3MD for Chronic Conditions, a Model for Motivational mHealth Design: Embedded Case Study. *JMIR Serious Games*, 6(3), p.e11631.

Glanz, K. and Bishop, D.B. (2010). The Role of Behavioural Science Theory in Development and Implementation of Public Health Interventions. *Annual Review of Public Health*, 31(1), pp.399–418.

Glanz, K., Rimer, B.K. and Viswanath, K. (2015). *Health Behaviour: Theory, Research, and Practice*. 5th ed. San Francisco: Jossey-Bass.

Glynn, L.G., Hayes, P.S., Casey, M., Glynn, F., Alvarez-Iglesias, A., Newell, J., ÓLaighin, G., Heaney, D., O'Donnell, M. and Murphy, A.W. (2014). Effectiveness of a Smartphone Application to Promote Physical Activity in Primary Care: The SMART MOVE Randomised Controlled Trial. *British Journal of General Practice*, 64(624), pp.e384–e391.

Gold, J., Walton, J., Cureton, P. and Anderson, L. (2011). Theorising and Practitioners in HRD: The Role of Abductive Reasoning. *Journal of European Industrial Training*, 35(3), pp.230–246.

Golden, S.D. and Earp, J.A.L. (2012). Social Ecological Approaches to Individuals and Their Contexts: Twenty Years of Health Education & Behaviour Health Promotion Interventions. *Health Education & Behaviour*, 39(3), pp.364–372.

Goldkuhl, G. (2004). *Meanings of Pragmatism: Ways to Conduct Information Systems Research*. [online] Available at: https://www.semanticscholar.org/paper/Meanings-of-Pragmatism%3A-Ways-to-conduct-information-Goldkuhl/cb0ac1af70a6ae0c6ff439f5c7449940a433e1d7 [Accessed 17 Jul. 2021].

Goldkuhl, G. (2009). Pragmatic Qualities of Information Systems: Actability Criteria for Design and Evaluation. In: *11th International Conference on Informatics and Semiotics in Organisations (ICISO)*. [online] pp.1–14. Available at: https://www.semanticscholar.org/paper/Pragmatic-Qualities-of-Information-Systems-%3A-for-Goldkuhl/d283a86cf133ebdec977c756d759b9e717aad814 [Accessed 15 Jul. 2021].

Goldkuhl, G. (2012a). Design Research in Search for a Paradigm: Pragmatism Is the Answer. In: *Communications in Computer and Information Science*. [online] pp.84–95. Available at: https://link.springer.com/chapter/10.1007%2F978-3-642-33681-2_8 [Accessed 15 Jul. 2021].

Goldkuhl, G. (2012b). Pragmatism vs Interpretivism in Qualitative Information Systems Research. *European Journal of Information Systems*, 21(2), pp.135–146.

Goldkuhl, G. (2020). Design Science Epistemology. A pragmatist inquiry. *Scandinavian Journal of Information Systems*, 32(1), pp.1–42.

Gomes, D. and Tzortzopoulos, P. (2018). Building Shared Understanding During Early Design. In: *26th Annual Conference of the International Group for Lean Construction*. [online] Available at: https://pure.hud.ac.uk/en/publications/building-shared-understanding-during-early-design [Accessed 17 Jul. 2021].

Gomes, D., Tzortzopoulos, P. and Kagioglou, M. (2016). Collaboration Through Shared

Understanding in Early Design Stage. In: *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*. [online] National Pingtung University of Science and Technology, pp.63–72. Available at: https://pure.hud.ac.uk/en/publications/collaboration-through-shared-understanding-in-early-design-stage [Accessed 17 Jul. 2021].

González, K., Fuentes, J. and Márquez, J.L. (2017). Physical Inactivity, Sedentary Behaviour and Chronic Diseases. *Korean Journal of Family Medicine*, 38(3), pp.111–115.

Google (2021). *Google Meet*. [online] Google Meet. Available at: https://meet.google.com/ [Accessed 17 Jul. 2021].

Google Play Store (2021). *Google Play Store: Android Apps*. [online] Google Play Store. Available at: https://play.google.com/store [Accessed 16 Jul. 2021].

Gourlan, M., Bernard, P., Bortolon, C., Romain, A.J., Lareyre, O., Carayol, M., Ninot, G. and Boiché, J. (2016). Efficacy of Theory-Based Interventions to Promote Physical Activity: A Meta-Analysis of Randomised Controlled Trials. *Health Psychology Review*, 10(1), pp.50–66.

Grant, C. and Osanloo, A.O. (2019). Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for Your "House." *Administrative Issues Journal: Connecting Education, Practice, and Research*, [online] 4(2), pp.12–26. Available at: https://aij.scholasticahq.com/article/7-understanding-selecting-and-integrating-a-theoretical-framework-in-dissertation-research-creating-the-blueprint-for-your-house [Accessed 17 Jul. 2021].

Gray, L., Wong-Wylie, G., Rempel, G. and Cook, K. (2020). Expanding Qualitative Research Interviewing Strategies: Zoom Video Communications. *The Qualitative Report*, 25(5), pp.1292–1301.

Green, L.W., Richard, L. and Potvin, L. (1996). Ecological Foundations of Health Promotion. *American Journal of Health Promotion*, 10(4), pp.270–281.

Gregor, S. and Hevner, A.R. (2013). Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, 37(2), pp.337–355.

Gregor, S. and Jones, D. (2007). The Anatomy of a Design Theory. *Journal of the Association*

*for Information Systems*, 8(5), pp.312–335.

Gregory, R. and Muntermann, J. (2011). Theorising in Design Science Research: Inductive versus Deductive Approaches. *ICIS 2011 Proceedings*. [online] Available at: https://aisel.aisnet.org/icis2011/proceedings/engagedscholarship/2/ [Accessed 15 Jul. 2021].

Gregory, R. and Muntermann, J. (2011). Theorising in Design Science Research: Inductive versus Deductive Approaches. In: *ICIS 2011 Proceedings*. [online] Available at: https://aisel.aisnet.org/icis2011/proceedings/engagedscholarship/2 [Accessed 17 Jul. 2021].

Griffin, L., Lee, D., Jaisle, A., Carek, P., George, T., Laber, E., Lok, B., Modave, F., Paskett, E. and Krieger, J. (2019). Creating an mHealth App for Colorectal Cancer Screening: User-Centered Design Approach. *JMIR Human Factors*, 6(2), p.e12700.

Groarke, J.M., Richmond, J., McSharry, J., Groarke, A., Harney, O., Kelly, M.G. and Walsh, J.C. (2021). Acceptability of a Mobile Health Behaviour Change Intervention for Cancer Survivors with Obesity/Overweight: A Nested Mixed-Methods Study within a Randomised Controlled Trial. *JMIR mHealth and uHealth*, 9(2).

Gruenewald, P.J., Remer, L.G. and LaScala, E.A. (2014). Testing a Social Ecological Model of Alcohol Use: The California 50-City Study. *Addiction*, 109(5), pp.736–745.

Guba, E.G. and Lincoln, Y.S. (1994). Competing Paradigms in Qualitative Research. In: N.K. Denzin and Y.S. Lincoln, eds., *Handbook of Qualitative Research*. Thousand Oaks: Sage Publications, pp.105–117.

Gubrium, J.F., Holstrin, J.A., Marvasti, A.B. and McKinney, K.D. (2012). *The SAGE Handbook of Interview Research: The Complexity of the Craft*. 2nd ed. Thousand Oaks: Sage Publications.

Guest, G., MacQueen, K.M. and Namey, E.E. (2012). *Applied Thematic Analysis*. Thousand Oaks, CA: Sage Publications.

Guo, C., Ashrafian, H., Ghafur, S., Fontana, G., Gardner, C. and Prime, M. (2020). Challenges for the Evaluation of Digital Health Solutions — A Call for Innovative Evidence

Generation Approaches. *NPJ Digital Medicine*, 3(1).

Guthold, R., Stevens, G.A., Riley, L.M. and Bull, F.C. (2018). Worldwide Trends in Insufficient Physical Activity from 2001 to 2016: A Pooled Analysis of 358 Population-Based Surveys with 1·9 Million Participants. *The Lancet Global Health*, 6(10), pp.e1077–e1086.

Guthold, R., Stevens, G.A., Riley, L.M. and Bull, F.C. (2020). Global Trends in Insufficient Physical Activity Among Adolescents: A Pooled Analysis of 298 Population-Based Surveys with 1·6 Million Participants. *The Lancet Child & Adolescent Health*, 4(1).

Haas, A. (2015). Crowding at the Frontier: Boundary Spanners, Gatekeepers and Knowledge Brokers. *EconPapers*. [online] Available at: https://econpapers.repec.org/paper/haljournl/hal-02313832.htm [Accessed 17 Jul. 2021].

Hacker, J., vom Brocke, J., Handali, J., Otto, M. and Schneider, J. (2020). Virtually in This Together – How Web-Conferencing Systems Enabled a New Virtual Togetherness During the COVID-19 Crisis. *European Journal of Information Systems*, 29(5), pp.1–22.

Hagger, M.S. and Weed, M. (2019). DEBATE: Do Interventions Based on Behavioural Theory Work in the Real World? *International Journal of Behavioural Nutrition and Physical Activity*, 16(1), pp.36–45.

Hagger, M.S., Keatley, D.A. and Chan, K.C.D. (2014). CALO-RE Taxonomy of Behaviour Change Techniques. In: R.C. Eklund and G. Tenenbaum, eds., *Encyclopedia of Sport and Exercise Psychology*. Thousand Oaks, CA: Sage Publications, pp.99–104.

Hagger, M.S., Moyers, S., McAnally, K. and McKinley, L.E. (2020). Known Knowns and Known Unknowns on Behaviour Change Interventions and Mechanisms of Action. *Health Psychology Review*, 14(1), pp.199–212.

Hall, G., Laddu, D.R., Phillips, S.A., Lavie, C.J. and Arena, R. (2021). A Tale of Two Pandemics: How Will COVID-19 and Global Trends in Physical Inactivity and Sedentary Behaviour Affect One Another? *Progress in Cardiovascular Diseases*, 64, pp.108–110.

Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W. and Ekelund, U. (2012).

Global Physical Activity Levels: Surveillance Progress, Pitfalls, and Prospects. *The Lancet*, 380(9838), pp.247–257.

Hamilton, K. and Miles, R. (2006). *Learning UML 2.0*. Newton, MA: O'Reilly.

Hanna, R. (2011). Kant's Non-Conceptualism, Rogue Objects, and the Gap in the B Deduction. *International Journal of Philosophical Studies*, 19(3), pp.399–415.

Hannula, O. (2014). *Game Structure in Knowledge Co-Creation*. PhD. Aalto University.

Hanschke, C., Baer, J., Gangaramany, A., Verheijen, J., Kilonzo, N., Okiya, B., Ranji, L.K., Amolo, S.A., Zwane, S., Nkambule, R., Buluma, V., Ojoo, S., Kim, S., Kibwana, S., Dybul, M. and Kretschmer, S. (2021). Supporting Communities of Practice – A Journey to Effective Problem-Solving. *Gates Open Research*, 4, p.110.

Haque, S. (2020). *Persuasive mHealth Behavioural Science Interventions to Promote Healthy Lifestyle*. PhD. University of Oulu.

Haradhan, M. (2017). Roles of Communities of Practice for the Development of the Society. *Journal of Economic Development, Environment and People*, 6(3), pp.27–46.

Harder, H., Holroyd, P., Burkinshaw, L., Watten, P., Zammit, C., Harris, P.R., Good, A. and Jenkins, V. (2017). A User-Centred Approach to Developing bWell, A Mobile App for Arm and Shoulder Exercises After Breast Cancer Treatment. *Journal of Cancer Survivorship*, 11(6), pp.732–742.

Harjumaa, M. (2014). *On the Development of Persuasive Systems: A Framework for Designing and Evaluating Behaviour Change Support Systems and its Applicability for e-Health*. PhD. Valtion Teknillinen Tutkimuskeskus (VTT) Technical Research Centre of Finland.

Harman, G.H. (1965). The Inference to the Best Explanation. *Philosophical Review*, 74(1), pp.88–95.

Harman, G.H. (1965). The Inference to the Best Explanation. *Philosophical Review*, 74(1), pp.88–95.

Harries, T., Eslambolchilar, P., Rettie, R., Stride, C., Walton, S. and van Woerden, H.C. (2016). Effectiveness of a Smartphone App in Increasing Physical Activity amongst Male

Adults: A Randomised Controlled Trial. *BMC Public Health*, 16(1).

Harries, T., Eslambolchilar, P., Stride, C., Rettie, R. and Walton, S. (2013). Walking in the Wild – Using an Always-On Smartphone Application to Increase Physical Activity. In: *14th International Conference on Human-Computer Interaction (INTERACT)*. [online] Springer, pp.19–36. Available at: https://hal.inria.fr/IFIP-LNCS-8120/hal-01510527 [Accessed 16 Jul. 2021].

Harris, J., Cale, L. and Hooper, O. (2021). The Promoting Active Lifestyles (PAL) Project: A Principle-Based Approach to Pedagogical Change. *The Curriculum Journal*, 32(1), pp.87–102.

Heffernan, K.J., Chang, S., Maclean, S.T., Callegari, E.T., Garland, S.M., Reavley, N.J., Varigos, G.A. and Wark, J.D. (2016). Guidelines and Recommendations for Developing Interactive eHealth Apps for Complex Messaging in Health Promotion. *JMIR mHealth and uHealth*, [online] 4(1), p.e4423. Available at: http://mhealth.jmir.org/2016/1/e14/ [Accessed 16 Jul. 2021].

Heiss, L. (2020). Iterative Prototypes as "Boundary Objects": Facilitating Interdisciplinary Collaboration of a Modular Hearing Aid. *The Design Journal*, 23(6), pp.865–883.

Hekler, E., King, A., Alonso, M. and Cirimele, J. (2011). A Case Study of BSUED: Behavioural Science-Informed User Experience Design. In: *CHI 2011*. [online] Available at: https://www.semanticscholar.org/paper/A-case-study-of-BSUED%3A-Behavioural-Science-informed-Hekler-King/33cc4133b2213de4759edc49d9a401e6965675fa [Accessed 17 Jul. 2021].

Hekler, E.B., Michie, S., Pavel, M., Rivera, D.E., Collins, L.M., Jimison, H.B., Garnett, C., Parral, S. and Spruijt-Metz, D. (2016). Advancing Models and Theories for Digital Behaviour Change Interventions. *American Journal of Preventive Medicine*, 51(5), pp.825–832.

Helf, C. and Hlavacs, H. (2016). Apps for Life Change: Critical Review and Solution Directions. *Entertainment Computing*, 14, pp.17–22.

Helfert, M., Donnellan, B. and Ostrowski, L. (2012). The Case for Design Science Utility and Quality - Evaluation of Design Science Artifact Within the Sustainable ICT Capability

Maturity Framework. *Systems, Signs & Actions*, 6(1), pp.46–66.

Henderson, K. (1991). Flexible Sketches and Inflexible Data Bases: Visual Communication, Conscription Devices, and Boundary Objects in Design Engineering. *Science, Technology, & Human Values*, 16(4), pp.448–473.

Henderson, K. (1998). The Role of Material Objects in the Design Process: A Comparison of Two Design Cultures and How They Contend with Automation. *Science, Technology, & Human Values*, 23(2), pp.139–174.

Hermano, M. and Stewart, G. (2014). Design Guidelines for a Mobile App for Wellbeing of Emerging Adults. In: *Proceedings of the 20th Americas Conference on Information Systems (AMCIS)*. [online] http://aisel.aisnet.org/: Association for Information Systems (AIS), pp.1–14. Available at: https://eprints.qut.edu.au/74571/ [Accessed 15 Jul. 2021].

Hermsen, S., van Essen, A., van Gessel, C., Bolster, E., van der Lugt, R. and Bloemen, M. (2020). Are Agile Design Approaches Useful in Designing for Health? A Case Study. In: *Design4Health 2020: Designing Future Health*. [online] pp.263–269. Available at: https://www.researchgate.net/publication/342600428_Are_agile_design_approaches_useful_in_designing_for_health_A_case_study [Accessed 16 Jul. 2021].

Heron, J. and Reason, P. (1997). A Participatory Inquiry Paradigm. *Qualitative Inquiry*, 3(3), pp.274–294.

Herselman, M. and Botha, A. (2015). Evaluating an Artifact in Design Science Research. In: *Proceedings of the 2015 Annual Research Conference on South African Institute of Computer Scientists and Information Technologists - SAICSIT '15*. [online] pp.1–10. Available at: https://dl.acm.org/doi/10.1145/2815782.2815806 [Accessed 17 Jul. 2021].

Hevner, A. (2007). A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*, 19(2), pp.87–92.

Hevner, A. and Chatterjee, S. (2010). *Design Research in Information Systems: Theory and Practice*. New York: Springer.

Hevner, A., March, S., Park, J. and Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, 28(1), pp.75–105.

Hevner, A., Prat, N., Comyn-Wattiau, I. and Akoka, J. (2018). A Pragmatic Approach for Identifying and Managing Design Science Research Goals and Evaluation Criteria. *AIS SIGPRAG: 6th Pre-ICIS Workshop "Practice-based Design and Innovation of Digital Artifacts", Association for Information Systems (AIS)*, [online] pp.1–15. Available at: https://ideas.repec.org/p/hal/journl/hal-02283783.html [Accessed 15 Jul. 2021].

Hevner, A., vom Brocke, J. and Maedche, A. (2018). Roles of Digital Innovation in Design Science Research. *Business & Information Systems Engineering*, 61(1), pp.3–8.

Hides, L., Kavanagh, D., Stoyanov, S., Zelenko, O., Tjondronegoro, D. and Mani, M. (2014). *Mobile Application Rating Scale (MARS): A New Tool for Assessing the Quality of Health Mobile Applications*. Abbotsford, VIC: Young and Well.

Higgins, J.P. (2016). Smartphone Applications for Patients' Health and Fitness. *The American Journal of Medicine*, 129(1), pp.11–19.

Hippocrates (1923). *Hippocrates, Volume I: Ancient Medicine. Airs, Waters, Places. Epidemics 1 and 3. The Oath. Precepts. Nutriment.* Translated by W.H.S. Jones. Cambridge: Harvard University Press.

Hirschheim, R. and Klein, H.K. (1989). Four Paradigms of Information Systems Development. *Communications of the ACM*, 32(10), pp.1199–1216.

Hoang Thuan, N., Drechsler, A. and Antunes, P. (2019). Construction of Design Science Research Questions. *Communications of the Association for Information Systems*, 44, pp.332–363.

Hoffmann, T.C., Glasziou, P.P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D.G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S.E., Dixon-Woods, M., McCulloch, P., Wyatt, J.C., Chan, A.W. and Michie, S. (2014). Better Reporting of Interventions: Template for Intervention Description and Replication (TIDieR) Checklist and Guide. *BMJ*, 348(3), pp.1–12.

Hollander, J.B., Folta, S.C., Graves, E.M., Allen, J.D. and Situ, M. (2021). A Fitness App for Monitoring Walking Behaviour and Perception (Runkeeper): Mixed Methods Pilot Study. *JMIR Formative Research*, 5(3), p.e22571.

Hölttä, V. (2013). *Beyound Boundary Object: Improving Engineering Communication with Conscription Devices*. PhD. Alto University.

Honary, M., Bell, B.T., Clinch, S., Wild, S.E. and McNaney, R. (2019). Understanding the Role of Healthy Eating and Fitness Mobile Apps in the Formation of Maladaptive Eating and Exercise Behaviours in Young People. *JMIR mHealth and uHealth*, 7(6), p.e14239.

Hosseinpour, M. and Terlutter, R. (2019). Your Personal Motivator is with You: A Systematic Review of Mobile Phone Applications Aiming at Increasing Physical Activity. *Sports Medicine*, 49(9), pp.1425–1447.

Howe, K.B., Suharlim, C., Ueda, P., Howe, D., Kawachi, I. and Rimm, E.B. (2016). Gotta Catch'em All! Pokémon GO and Physical Activity Among Young Adults: Difference in Differences Study. *BMJ*, 355, pp.1–4.

Howlett, N. (2018). *Evidence-Based and Theoretically-Driven Behaviour Change Interventions for Physical Activity to Enhance Health and Wellbeing*. PhD. University of Hertfordshire.

Howlett, N., Trivedi, D., Troop, N.A. and Marie Chater, A. (2015). What are the Most Effective Behaviour Change Techniques to Promote Physical Activity and/or Reduce Sedentary Behaviour in Inactive Adults? A Systematic Review Protocol. *BMJ Open*, 5(8), pp.1–7.

Howley, E.T. (2001). Type of Activity: Resistance, Aerobic and Leisure versus Occupational Physical Activity. *Medicine and Science in Sports and Exercise*, 33(6), pp.S364–S369.

Huang, J., Zou, Y., Huang, W., Zhou, Y., Lin, S., Chen, J. and Lan, Y. (2020). Factors Associated with Physical Activity in Elderly Nursing Home Residents: A Path Analysis. *BMC Geriatrics*, 20(1), pp.274–273.

Huber, M. (2014). *Towards a New, Dynamic Concept of Health: Its Operationalisation and Use in Public Health and Healthcare, and in Evaluating Health Effects of Food*. PhD. Maastricht University.

Huber, M., Knottnerus, J.A., Green, L., Horst, H. v. d., Jadad, A.R., Kromhout, D., Leonard, B., Lorig, K., Loureiro, M.I., Meer, J.W.M. v. d., Schnabel, P., Smith, R., Weel, C. v. and Smid, H. (2011). How Should We Define Health? *BMJ*, 343(d4163), pp.1–3.

Huber, M., Vliet, M. van, Giezenberg, M., Winkens, B., Heerkens, Y., Dagnelie, P.C. and Knottnerus, J.A. (2016). Towards a "Patient-Centred" Operationalisation of the New Dynamic Concept of Health: A Mixed Methods Study. *BMJ Open*, [online] 6(1). Available at: https://pubmed.ncbi.nlm.nih.gov/26758267/ [Accessed 15 Jul. 2021].

Hunter, R.F., de la Haye, K., Murray, J.M., Badham, J., Valente, T.W., Clarke, M. and Kee, F. (2019). Social Network Interventions for Health Behaviours and Outcomes: A Systematic Review and Meta-Analysis. *PLOS Medicine*, 16(9), pp.1–25.

Huppert, L.A. and Babik, J.M. (2020). Best Practices to Successfully Navigate a Virtual Interview: a Five-Step Guide for Hematology/Oncology Fellowship Applicants. *Journal of Cancer Education*. [online] Available at: https://link.springer.com/article/10.1007%2Fs13187-020-01851-w [Accessed 17 Jul. 2021].

Huvila, I., Anderson, T.D., Jansen, E.H., McKenzie, P. and Worrall, A. (2016). Boundary Objects in Information Science. *Journal of the Association for Information Science and Technology*, 68(8), pp.1807–1822.

Iivari, J. (2007). A Paradigmatic Analysis of Information Systems as a Design Science. *Scandinavian Journal of Information Systems*, 19(2), pp.39–64.

Iivari, J. (2020). Editorial: A Critical Look at Theories in Design Science Research. *Journal of the Association for Information Systems*, 21(3), pp.502–519.

Iivari, J. and Venable, J. (2009). Action Research and Design Science Research - Seemingly Similar but Decisively Dissimilar. *ECIS 2009 Proceedings*, [online] 73. Available at: https://aisel.aisnet.org/ecis2009/73/ [Accessed 17 Jul. 2021].

Iivari, N. (2019). Discursive Struggles within Cross-Disciplinary Design. In: *ICIS 2019 Proceedings*. [online] Available at: https://aisel.aisnet.org/icis2019/design_science/design_science/5/ [Accessed 17 Jul. 2021].

Imenda, S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? *Journal of Social Sciences*, 38(2), pp.185–195.

IMT Innovation (2021). *Digital Health*. [online] Innovatemedtec. Available at: https://innovatemedtec.com/digital-health [Accessed 16 Jul. 2021].

Institute of Medicine (2002). *The Future of the Public's Health in the 21st Century*. [online] Washington, DC: National Academies Press. Available at: https://www.ncbi.nlm.nih.gov/books/NBK221239/ [Accessed 16 Jul. 2021].

International Organisation for Standardisation (2010). *Ergonomics of Human-System Interaction (ISO 9241)*. [online] International Organisation for Standardisation. Available at: https://www.iso.org/standard/52075.html [Accessed 16 Jul. 2021].

Islind, A.S., Lindroth, T., Lundin, J. and Steineck, G. (2019). Co-Designing a Digital Platform with Boundary Objects: Bringing Together Heterogeneous Users in Healthcare. *Health and Technology*, 9(4), pp.425–438.

Jabareen, Y. (2009). Building a Conceptual Framework: Philosophy, Definitions, and Procedure. *International Journal of Qualitative Methods*, 8(4), pp.49–62.

Jacobs, M.A. and Graham, A.L. (2016). Iterative Development and Evaluation Methods of mHealth Behaviour Change Interventions. *Current Opinion in Psychology*, 9, pp.33–37.

Jadad, A.R. and O'Grady, L. (2008). How Should Health be Defined? *BMJ*, 10(337), p.a2900.

Jake-Schoffman, D.E. and McVay, M.A. (2020). Using the Design Sprint Process to Enhance and Accelerate Behavioural Medicine Progress: A Case Study and Guidance. *Translational Behavioural Medicine*, 11(5), pp.1099–1106.

Jambroes, M., Nederland, T., Kaljouw, M., van Vliet, K., Essink-Bot, M.L. and Ruwaard, D. (2015). Implications of Health as "The Ability to Adapt and Self-Manage" for Public Health Policy: A Qualitative Study. *The European Journal of Public Health*, 26(3), pp.412–416.

Janz, N.K. and Becker, M.H. (1984). The Health Belief Model: A Decade Later. *Health Education Quarterly*, 11(1), pp.1–47.

Järvinen, P. (2007). Action Research is Similar to Design Science. *Quality & Quantity*, 41(1), pp.37–54.

Jaspers, L., Colpani, V., Chaker, L., van der Lee, S.J., Muka, T., Imo, D., Mendis, S., Chowdhury, R., Bramer, W.M., Falla, A., Pazoki, R. and Franco, O.H. (2014). The Global Impact of Noncommunicable Diseases on Households and Impoverishment: A Systematic Review. *European Journal of Epidemiology*, 30(3), pp.163–188.

Jee, H. (2017). Review of Researches on Smartphone Applications for Physical Activity Promotion in Healthy Adults. *Journal of Exercise Rehabilitation*, 13(1), pp.3–11.

Jensenius, A.R. (2012). Disciplinarities: Intra, Cross, Multi, Inter, Trans. *ARJ*. Available at: https://www.arj.no/2012/03/12/disciplinarities-2/ [Accessed 17 Jul. 2021].

Johannesson, P. and Perjons, E. (2012). *A Design Science Primer*. Scotts Valley, CA: CreateSpace.

Johnson, M.P., Ballie, J., Thorup, T. and Brooks, E. (2017). Living on the Edge: Design Artefacts as Boundary Objects. *The Design Journal*, 20(S1), pp.S219–S235.

Johnston, M., Carey, R.N., Connell Bohlen, L.E., Johnston, D.W., Rothman, A.J., de Bruin, M., Kelly, M.P., Groarke, H. and Michie, S. (2021). Development of an Online Tool for Linking Behaviour Change Techniques and Mechanisms of Action Based on Triangulation of Findings from Literature Synthesis and Expert Consensus. *Translational Behavioural Medicine*, 11(5), pp.1049–1065.

Johnston, M., Mobasheri, M., King, D. and Darzi, A. (2015). The Imperial Clarify, Design and Evaluate (CDE) Approach to mHealth App Development. *BMJ Innovations*, 1(2), pp.39–42.

Josephson, J.R. and Josephson, S.G. (1996). Conceptual Analysis of Abduction. In: *Abductive Inference - Computation, Philosophy & Technology*. Cambridge: Cambridge University Press, pp.1–29.

Jusoh, S. (2017). A Survey on Trend, Opportunities and Challenges of mHealth Apps. *International Journal of Interactive Mobile Technologies (IJIM)*, 11(6), pp.73–85.

Kamlah, W. and Lorenzen, P. (1984). *Logical Propaedeutic: Pre-school of Reasonable Discourse*. New York: University Press of America.

Kant, I. (1922). *Critique of Pure Reason*. 2nd ed. Translated by F.M. Müller. New York: The

MacMillan Company.

Kanwal, S., Nunes, M.B., Hui, M.A.C. and Madden, A.D. (2019). Application of Boundary Objects in Knowledge Management Research: A Review. *Electronic Journal of Knowledge Management*, 17(2), p.100-113.

Kao, C.K. and Liebovitz, D.M. (2017). Consumer Mobile Health Apps: Current State, Barriers, and Future Directions. *PM&R*, 9(S5), pp.S106–S115.

Kaptein, M., Markopoulos, P., de Ruyter, B. and Aarts, E. (2015). Personalising Persuasive Technologies: Explicit and Implicit Personalisation Using Persuasion Profiles. *International Journal of Human-Computer Studies*, 77, pp.38–51.

Kasali, F.A., Awodele, O., Kuyoro, S., Akinsanya, A. and Eze, M. (2017). A Conceptual Design and Evaluation Framework for Mobile Persuasive Health Technologies (Usability Approach). *Research Journal of Mathematics and Computer Science*, 1(4), pp.1–16.

Kelechi, T.J., Prentice, M.A., Mueller, M., Madisetti, M. and Vertegel, A. (2020). A Lower Leg Physical Activity Intervention for Individuals with Chronic Venous Leg Ulcers: Randomised Controlled Trial. *JMIR mHealth and uHealth*, 8(5), p.e15015.

Kelly, M.P. and Barker, M. (2016). Why is Changing Health-Related Behaviour So Difficult? *Public Health*, 136, pp.109–116.

Kemmis, S. and Smith, T.J. (2008). *Enabling Praxis: Challenges for Education*. Rotterdam: Sense Publishers.

Kensing, F. and Blomberg, J. (1998). Participatory Design: Issues and Concerns. *Computer Supported Cooperative Work (CSCW)*, 7(3-4), pp.167–185.

Keselman, A., Logan, R., Smith, C.A., Leroy, G. and Zeng-Treitler, Q. (2008). Developing Informatics Tools and Strategies for Consumer-centered Health Communication. *Journal of the American Medical Informatics Association*, 15(4), pp.473–483.

Khaled, R. and Vasalou, A. (2014). Bridging Serious Games and Participatory Design. *International Journal of Child-Computer Interaction*, 2(2), pp.93–100.

Khamzina, M., Parab, K.V., An, R., Bullard, T. and Grigsby-Toussaint, D.S. (2020). Impact of Pokémon Go on Physical Activity: A Systematic Review and Meta-Analysis. *American Journal of Preventive Medicine*, 58(2), pp.270–282.

Khisro, J. and Persson-Slumpi, T. (2019). Identifying Traces of Boundary Object Properties in Data Hub Development Narratives: Two Cases from Scandinavian Electricity Market. In: *AMCIS 2019 Proceedings*. [online] Available at: http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-36946 [Accessed 17 Jul. 2021].

Kickbusch, I. (2019). Health Promotion 4.0. *Health Promotion International*, 34(2), pp.179–181.

Kim, J., Marcusson-Clavertz, D., Yoshiuchi, K. and Smyth, J.M. (2019). Potential Benefits of Integrating Ecological Momentary Assessment Data into mHealth Care Systems. *BioPsychoSocial Medicine*, 13(1).

Kim, Y., Seo, J., An, S., Sinn, D.H. and Hwang, J.H. (2020). Efficacy and Safety of an mHealth App and Wearable Device in Physical Performance for Patients with Hepatocellular Carcinoma: Development and Usability Study. *JMIR mHealth and uHealth*, 8(3), pp.1–13.

King, A.C., Hekler, E.B., Grieco, L.A., Winter, S.J., Sheats, J.L., Buman, M.P., Banerjee, B., Robinson, T.N. and Cirimele, J. (2013). Harnessing Different Motivational Frames via Mobile Phones to Promote Daily Physical Activity and Reduce Sedentary Behaviour in Aging Adults. *PLOS ONE*, 8(4), pp.1–8.

King, A.C., Hekler, E.B., Grieco, L.A., Winter, S.J., Sheats, J.L., Buman, M.P., Banerjee, B., Robinson, T.N. and Cirimele, J. (2016). Effects of Three Motivationally Targeted Mobile Device Applications on Initial Physical Activity and Sedentary Behaviour Change in Midlife and Older Adults: A Randomised Trial. *PLOS ONE*, 11(6), pp.1–16.

Kinnunen, J. (2018). *Role of Boundary Objects in Knowledge Co-Creation: A Case Study of a Service Co-Design Workshop*. Masters. Aalto University.

Kirwan, M., Duncan, M.J., Vandelanotte, C. and Mummery, W.K. (2012a). Design, Development, and Formative Evaluation of a Smartphone Application for Recording and Monitoring Physical Activity Levels. *Health Education & Behaviour*, 40(2), pp.140–

151.

Kirwan, M., Duncan, M.J., Vandelanotte, C. and Mummery, W.K. (2012b). Using Smartphone Technology to Monitor Physical Activity in the 10,000 Steps Program: A Matched Case–Control Trial. *Journal of Medical Internet Research*, 14(2), p.e55.

Klasnja, P., Consolvo, S. and Pratt, W. (2011). How to Evaluate Technologies for Health Behaviour Change in HCI Research. In: *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. pp.3063–3072.

Klasnja, P., Hekler, E.B., Korinek, E.V., Harlow, J. and Mishra, S.R. (2017). Toward Usable Evidence: Optimizing Knowledge Accumulation in HCI Research on Health Behaviour Change. In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. pp.3071–3082.

Klonoff, D.C. (2019). Behavioural Theory: The Missing Ingredient for Digital Health Tools to Change Behaviour and Increase Adherence. *Journal of Diabetes Science and Technology*, 13(2), pp.276–281.

Knight, E., Stuckey, M.I., Prapavessis, H. and Petrella, R.J. (2015). Public Health Guidelines for Physical Activity: Is There an App for That? A Review of Android and Apple App Stores. *JMIR mHealth and uHealth*, 3(2), p.e43.

Knittle, K., Morrison, L., Inauen, J., Warner, L.M., Kassavou, K., Naughton, F. and Michie, S. (2016). mHealth: Past Success, Future Challenges, and the Role of the EHPS. *European Health Psychologist*, [online] 18(6), pp.266–272. Available at: https://www.dora.lib4ri.ch/eawag/islandora/object/eawag%3A14077 [Accessed 17 Jul. 2021].

Knittle, K., Nurmi, J., Crutzen, R., Hankonen, N., Beattie, M. and Dombrowski, S.U. (2018). How Can Interventions Increase Motivation for Physical Activity? A Systematic Review and Meta-Analysis. *Health Psychology Review*, 12(3), pp.211–230.

Kohl, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G. and Kahlmeier, S. (2012). The Pandemic of Physical Inactivity: Global Action for Public Health. *The Lancet*, 380(9838), pp.294–305.

Kok, G., Gottlieb, N.H., Peters, G.J.Y., Mullen, P.D., Parcel, G.S., Ruiter, R.A.C., Fernández, M.E., Markham, C. and Bartholomew, L.K. (2016). A Taxonomy of Behaviour Change Methods: An Intervention Mapping Approach. *Health Psychology Review*, 10(3), pp.297–312.

Koorts, H., Eakin, E., Estabrooks, P., Timperio, A., Salmon, J. and Bauman, A. (2018). Implementation and Scale Up of Population Physical Activity Interventions for Clinical and Community Settings: The PRACTIS Guide. *International Journal of Behavioural Nutrition and Physical Activity*, 15(1), pp.51–61.

Koppenhagen, N. (2013). *Design Principles for Supply Nework Systems*. PhD. Universitat Mannheim.

Korstjens, I. and Moser, A. (2017). Series: Practical Guidance to Qualitative research. Part 4: Trustworthiness and Publishing. *European Journal of General Practice*, 24(1), pp.120–124.

Koskela, L., Pikas, E., Gomes, D., Biotto, C., Talebi, S., Rahim, N. and Tzortzopoulos, P. (2016). Towards Shared Understanding on Common Ground, Boundary Objects and Other Related Concepts. In: *The 24th Annual Conference of the International Group for Lean Construction*. [online] pp.63–72. Available at: http://eprints.hud.ac.uk/id/eprint/29053/ [Accessed 17 Jul. 2021].

Kosonen, E. (2015). *Mixed Mode Communication for Knowledge Co-Creation in Networked Organisations*. Masters. Aalto University.

Kostkova, P. (2015). Grand Challenges in Digital Health. *Frontiers in Public Health*, 3, pp.1–5.

Kothari, A., Edwards, N., Yanicki, S., Hansen-Ketchum, P. and Kennedy, M.A. (2007). Socioecological Models: Strengthening Intervention Research in Tobacco Control. *Drogues Santé et Société*, 6(6), pp.1–24.

Kowatsch, T., Otto, L., Harperink, S., Cotti, A. and Schlieter, H. (2019). A Design and Evaluation Framework for Digital Health Interventions. *Information Technology*, 61(5-6), pp.253–263.

Kramer, J.N., Künzler, F., Mishra, V., Presset, B., Kotz, D., Smith, S., Scholz, U. and Kowatsch, T. (2019). Investigating Intervention Components and Exploring States of Receptivity for a Smartphone App to Promote Physical Activity: Protocol of a Microrandomised Trial. *JMIR Research Protocols*, 8(1), p.e11540.

Kuechler, B. and Vaishnavi, V. (2008). On Theory Development in Design Science Research: Anatomy of a Research Project. *European Journal of Information Systems*, 17(5), pp.489–504.

Kwasnicka, D., Dombrowski, S.U., White, M. and Sniehotta, F. (2016). Theoretical Explanations for Maintenance of Behaviour Change: A Systematic Review of Behaviour Theories. *Health Psychology Review*, 10(3), pp.277–296.

Kwasnicka, D., Vandelanotte, C., Rebar, A., Gardner, B., Short, C., Duncan, M., Crook, D. and Hagger, M.S. (2017). Comparing Motivational, Self-Regulatory and Habitual Processes in a Computer-Tailored Physical Activity Intervention in Hospital Employees - Protocol for the PATHS Randomised Controlled Trial. *BMC Public Health*, 17(1), pp.518–534.

Laato, S., Hyrynsalmi, S., Rauti, S. and Sutinen, E. (2020). The Effects Playing Pokémon GO has on Physical Activity - A Systematic Literature Review. In: *Proceedings of the 53rd Hawaii International Conference on System Sciences*. [online] Available at: https://hdl.handle.net/10125/64159 [Accessed 16 Jul. 2021].

Lachman, M.E., Lipsitz, L., Lubben, J., Castaneda-Sceppa, C. and Jette, A.M. (2018). When Adults Don't Exercise: Behavioural Strategies to Increase Physical Activity in Sedentary Middle-Aged and Older Adults. *Innovation in Aging*, 2(1), pp.1–12.

Lai, A.M., Hsueh, P.Y. . S., Choi, Y.K. and Austin, R.R. (2017). Present and Future Trends in Consumer Health Informatics and Patient-Generated Health Data. *Yearbook of Medical Informatics*, 26(1), pp.152–159.

Lai, B., Wilroy, J., Young, H.J., Howell, J., Rimmer, J.H., Mehta, T. and Thirumalai, M. (2019). A Mobile App to Promote Adapted Exercise and Social Networking for People with Physical Disabilities: Usability Study. *JMIR Formative Research*, 3(1), p.e11689.

Lakhani, J., Benzies, K. and Hayden, K.A. (2012). Attributes of Interdisciplinary Research

Teams: A Comprehensive Review of the Literature. *Clinical and Investigative Medicine. Medecine Clinique Et Experimentale*, [online] 35(5), p.e226. Available at: https://pubmed.ncbi.nlm.nih.gov/23043705/ [Accessed 17 Jul. 2021].

Langley, J., Wolstenholme, D. and Cooke, J. (2018). "Collective Making" as Knowledge Mobilisation: The Contribution of Participatory Design in the Co-Creation of Knowledge in Healthcare. *BMC Health Services Research*, 18(1), pp.1–10.

Langrial, S. (2014). *Exploring the Influence of Persuasive Reminders and Virtual Rehearsal on the Efficacy of Health Behaviour Change Support System*. PhD. University of Oulu.

Laranjo, L., Arguel, A., Neves, A.L., Gallagher, A.M., Kaplan, R., Mortimer, N., Mendes, G.A. and Lau, A.Y.S. (2015). The Influence of Social Networking Sites on Health Behaviour Change: A Systematic Review and Meta-Analysis. *Journal of the American Medical Informatics Association: JAMIA*, 22(1), pp.243–56.

Laranjo, L., Ding, D., Heleno, B., Kocaballi, B., Quiroz, J.C., Tong, H.L., Chahwan, B., Neves, A.L., Gabarron, E., Dao, K.P., Rodrigues, D., Neves, G.C., Antunes, M.L., Coiera, E. and Bates, D.W. (2020). Do Smartphone Applications and Activity Trackers Increase Physical Activity in Adults? Systematic Review, Meta-Analysis and Metaregression. *British Journal of Sports Medicine*, 55(8), pp.422–432.

Larson, J.S. (1999). The Conceptualisation of Health. *Medical Care Research and Review*, 56(2), pp.123–136.

Larsson, E. (2015). *Challenging Persuasive Principles in Mobile Applications*. PhD. Blekinge Institute of Technology.

Latour, C. (1987). *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge: Harvard University Press.

Lave, J. (1988). *Cognition in Practice: Mind, Mathematics, and Culture in Everyday Life*. Cambridge: Cambridge University Press.

Law, J. (1986). On Methods of Long-Distance Control: Vessels, Navigation and the Portuguese Route to India. In: J. Law, ed., *Power, Action and Belief: A New Sociology of Knowledge?* London: Routledge, pp.234–263.

Lawo, D., Esau, M., Engelbutzeder, P. and Stevens, G. (2020). Going Vegan: The Role(s) of ICT in Vegan Practice Transformation. *Sustainability*, 12(12), p.5184.

Laxman, K., Krishnan, S.B. and Dhillon, J.S. (2015). Barriers to Adoption of Consumer Health Informatics Applications for Health Self-Management. *Health Science Journal*, 9(5), pp.7–13.

LeBlanc, A.G. and Chaput, J.P. (2017). Pokémon Go: A Game Changer for the Physical Inactivity Crisis? *Preventive Medicine*, 101, pp.235–237.

Lee, A.M., Chavez, S., Bian, J., Thompson, L.A., Gurka, M.J., Williamson, V.G. and Modave, F. (2019). Efficacy and Effectiveness of Mobile Health Technologies for Facilitating Physical Activity in Adolescents: Scoping Review. *JMIR mHealth and uHealth*, 7(2), p.e11847.

Lee, A.S. and Baskerville, R.L. (2003). Generalising Generalisability in Information Systems Research. *Information Systems Research*, 14(3), pp.221–243.

Lee, C.P. (2007). Boundary Negotiating Artifacts: Unbinding the Routine of Boundary Objects and Embracing Chaos in Collaborative Work. *Computer Supported Cooperative Work (CSCW)*, 16(3), pp.307–339.

Lee, D., Frey, G., Cheng, A. and Shih, P.C. (2018b). Puzzle Walk: A Gamified Mobile App to Increase Physical Activity in Adults with Autism Spectrum Disorder. In: *2018 10th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*.

Lee, D., Frey, G.C., Min, A., Kim, B., Cothran, D.J., Bellini, S., Han, K. and Shih, P.C. (2020). Usability Inquiry of a Gamified Behaviour Change App for Increasing Physical Activity and Reducing Sedentary Behaviour in Adults With and Without Autism Spectrum Disorder. *Health Informatics Journal*, 26(4), pp.2992–3008.

Lee, I., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N. and Katzmarzyk, P.T. (2012). Effect of Physical Inactivity on Major Noncommunicable Diseases Worldwide: An Analysis of Burden of Disease and Life Expectancy. *The Lancet*, 380(9838), pp.219–229.

Lee, J.S., Pries-Heje, J. and Baskerville, R. (2011). Theorising in Design Science Research. In:

*Service-Oriented Perspectives in Design Science Research - 6th International Conference on Design Science Research in Information Systems (DESRIST) 2011 Proceedings*. [online] pp.1–16. Available at: https://link.springer.com/chapter/10.1007%2F978-3-642-20633-7_1 [Accessed 15 Jul. 2021].

Lee, M., Lee, H., Kim, Y., Kim, J., Cho, M., Jang, J. and Jang, H. (2018a). Mobile App-Based Health Promotion Programs: A Systematic Review of the Literature. *International Journal of Environmental Research and Public Health*, 15(12), pp.2838–2850.

Leon, A.S. (1985). Physical Activity Levels and Coronary Heart Disease: Analysis of Epidemiologic and Supporting Studies. *Medical Clinics of North America*, 69(1), pp.3–20.

Leonardi, F. (2018). The Definition of Health: Towards New Perspectives. *International Journal of Health Services*, 48(4), pp.735–748.

Levina, N. and Vaast, E. (2005). The Emergence of Boundary Spanning Competence in Practice: Implications for Implementation and Use of Information Systems. *MIS Quarterly*, 29(2), pp.335–363.

Liew, M.S., Zhang, J., See, J. and Ong, Y.L. (2019). Usability Challenges for Health and Wellness Mobile Apps: Mixed-Methods Study Among mHealth Experts and Consumers. *JMIR mHealth and uHealth*, 7(1), p.e12160.

Lincoln, Y.S. and Guba, E.G. (1985). *Naturalistic Inquiry*. Newbury Park, CA: Sage Publications.

Lincoln, Y.S. and Guba, E.G. (1986). But is it Rrigorous? Trustworthiness and Authenticity in Naturalistic Evaluation. *New Directions for Program Evaluation*, 1986(30), pp.73–84.

Little, L., Sillence, E. and Joinson, A. (2017). *Behaviour Change Research and Theory: Psychological and Technological Perspectives*. London: Academic Press.

Liu, C., Shao, S., Liu, C., Bennett, G.G., Prvu Bettger, J. and Yan, L.L. (2019). Academia–Industry Digital Health Collaborations: A Cross-Cultural Analysis of Barriers and Facilitators. *Digital Health*, 5, pp.1–9.

Liu, Y. and Avello, M. (2021). Status of the Research in Fitness Apps: A Bibliometric Analysis. *Telematics and Informatics*, 57, pp.1–18.

Locke, E.A. and Latham, G.P. (2002). Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey. *American Psychologist*, 57(9), pp.705–717.

Long, J.C., Cunningham, F.C. and Braithwaite, J. (2013). Bridges, Brokers and Boundary Spanners in Collaborative Networks: A Systematic Review. *BMC Health Services Research*, 13(1).

Lopez, M., Luyten, K., Vanacken, D. and Coninx, K. (2018). Exploring the Role of Artefacts to Coordinate Design Meetings. *The Journal of Interaction Science*, [online] 6, p.23. Available at: https://jois.online/index.php/jois/article/view/46 [Accessed 17 Jul. 2021].

Lu, H. and Ho, H. (2020). Exploring the Impact of Gamification on Users' Engagement for Sustainable Development: A Case Study in Brand Applications. *Sustainability*, 12(10), p.4169.

Lucivero, F. and Prainsack, B. (2015). The Lifestylisation of Healthcare? "Consumer Genomics" and Mobile Health as Technologies for Healthy Lifestyle. *Applied & Translational Genomics*, 4, pp.44–49.

Luguri, J. and Strahilevitz, L.J. (2021). Shining a Light on Dark Patterns. *Journal of Legal Analysis*, 13(1), pp.43–109.

Lukyanenko, R. and Parsons, J. (2013). Reconciling Theories with Design Choices in Design Science Research. In: J. vom Brocke, R. Hekkala, S. Ram and M. Rossi, eds., *Design Science at the Intersection of Physical and Virtual Design*. Berlin: Springer, pp.165–180.

Lupanda, S. (2018). *Designing a Mobile Application for the Trading of Used Books at a University: A DSR Approach*. Masters. North West University.

Lupiáñez-Villanueva, F., Folkvord, F. and Vanden Abeele, M. (2020). Influence of the Business Revenue, Recommendation, and Provider Models on Mobile Health App Adoption: Three-Country Experimental Vignette Study. *JMIR mHealth and uHealth*, 8(6), pp.1–13.

Lynch, M. and Metcalf, M. (2006). Reflection, Pragmatism, Concets and Intuition. *Journal of*

*Information Technology Theory and Application (JITTA)*, [online] 7(4). Available at: https://aisel.aisnet.org/jitta/vol7/iss4/3/ [Accessed 17 Jul. 2021].

Maarouf, H. (2019). Pragmatism as a Supportive Paradigm for the Mixed Research Approach: Conceptualizing the Ontological, Epistemological, and Axiological Stances of Pragmatism. *International Business Research*, 12(9), pp.1–12.

Magnani, L. (2005). An Abductive Theory of Scientific Reasoning. *Semiotica*, 153, pp.261–286.

Mahmood, A., Kedia, S., Wyant, D.K., Ahn, S. and Bhuyan, S.S. (2019). Use of Mobile Health Applications for Health-Promoting Behaviour Among Individuals with Chronic Medical Conditions. *Digital Health*, 5, pp.1–17.

Majchrzak, A., More, P.H.B. and Faraj, S. (2012). Transcending Knowledge Differences in Cross-Functional Teams. *Organisation Science*, 23(4), pp.951–970.

Mala, D.J. (2019). *Integrating the Internet of Things into Software Engineering Practices*. Hershey: IGI Global.

Mandviwalla, M. (2015). Generating and Justifying Design Theory. *Journal of the Association for Information Systems*, 16(5), pp.314–344.

March, S.T. and Smith, G.F. (1995). Design and Natural Science Research on Information Technology. *Decision Support Systems*, 15(4), pp.251–266.

March, S.T. and Storey, V.C. (2008). Design Science in the Information Systems Discipline: An Introduction to the Special Issue on Design Science Research. *MIS Quarterly*, 32(4), pp.725–730.

Marques, M., Matos, M., Mattila, E., Encantado, J., Duarte, C., Teixeira, P., Stubbs, R., Sniehotta, F., Ermes, M., Harjumaa, M., Leppänen, J., Välkkynen, P., Silva, M., Ferreira, C., Carvalho, S., Palmeira, L., Horgan, G., Heitmann, B., Evans, E. and Palmeira, A. (2020). Development of a Theory and Evidence-Based Digital Intervention Tool for Weight Loss Maintenance: The NoHoW Toolkit. *Journal of Medical Internet Research*.

Martin, A., Caon, M., Adorni, F., Andreoni, G., Ascolese, A., Atkinson, S., Bul, K., Carrion, C., Castell, C., Ciociola, V., Condon, L., Espallargues, M., Hanley, J., Jesuthasan, N.,

Lafortuna, C.L., Lang, A., Prinelli, F., Puidomenech Puig, E., Tabozzi, S.A. and McKinstry, B. (2020). A Mobile Phone Intervention to Improve Obesity-Related Health Behaviours of Adolescents Across Europe: Iterative Co-Design and Feasibility Study. *JMIR mHealth and uHealth*, 8(3), pp.1–16.

Martinsons, M.G., Davison, R.M. and Ou, C.X. (2015). Developing a New Theory of Knowledge Sharing: Documenting and Reflecting on a Messy Process. *Academy of Management Proceedings*, 2015(1), pp.1–38.

Maslow, A.H. (1943). A Theory of Human Motivation. *Psychological Review*, 50(4), pp.370–396.

Mason, M. (2010). Sample Size and Saturation in PhD Studies Using Qualitative Interviews. *Methods for Qualitative Management Research in the Context of Social Systems Thinking*, 11(3).

Matilainen, A., Suutari, T., Lähdesmäki, M. and Koski, P. (2018). Management by Boundaries – Insights into the Role of Boundary Objects in a Community-Based Tourism Development Project. *Tourism Management*, 67, pp.284–296.

Matthews, J., Win, K.T., Oinas-Kukkonen, H. and Freeman, M. (2016). Persuasive Technology in Mobile Applications Promoting Physical Activity: a Systematic Review. *Journal of Medical Systems*, 40(3), pp.72–84.

Matthews, L., Pugmire, J., Moore, L., Kelson, M., McConnachie, A., McIntosh, E., Morgan-Trimmer, S., Murphy, S., Hughes, K., Coulman, E., Utkina-Macaskill, O. and Simpson, S.A. (2017). Study Protocol for the "HelpMeDoIt!" Randomised Controlled Feasibility Trial: An App, Web and Social Support-Based Weight Loss Intervention for Adults with Obesity. *BMJ Open*, 7(10), p.e017159.

Mayo, A.T. and Woolley, A.W. (2016). Teamwork in Health Care: Maximizing Collective Intelligence via Inclusive Collaboration and Open Communication. *The AMA Journal of Ethic*, 18(9), pp.933–940.

McCallum, C.H. (2019). *Evaluating the Impact of Physical Activity Apps and Wearables: An Interdisciplinary Investigation of Research Designs and Method*. PhD. University of Glasgow.

McCarthy, S., O'Raghallaigh, P., Fitzgerald, C. and Adam, F. (2020). Building Bridges, Burning Bridges: The Use of Boundary Objects in Agile Distributed ISD Teams. In: *Proceedings of the 53rd Hawaii International Conference on System Sciences*. [online] pp.512–521. Available at: https://hdl.handle.net/10125/63802 [Accessed 17 Jul. 2021].

McGill, V.J. (1939). Pragmatism Reconsidered: An Aspect of John Dewey's Philosophy. *Science & Society*, 3(3), pp.289–322.

McKay, F.H., Slykerman, S. and Dunn, M. (2019). The App Behaviour Change Scale: Creation of a Scale to Assess the Potential of Apps to Promote Behaviour Change. *JMIR mHealth and uHealth*, 7(1), pp.1–17.

McKenzie, R.T. (1909). *Exercise in Education and Medicine*. London: Saunders Company.

McLaren, L. and Hawe, P. (2005). Ecological perspectives in health research. *Journal of Epidemiology & Community Health*, 59(1), pp.6–14.

McLaughlin, N., Takami, T. and Lin, C. (2020). *Physical Inactivity Crisis & the COVID-19 Pandemic: Time is Now to Implement Exercise as Medicine in Medical School Teaching*. [online] Harvard Medical Student Review. Available at: https://www.hmsreview.org/covid/physical-inactivity-crisis [Accessed 16 Jul. 2021].

McLeroy, K.R., Bibeau, D., Steckler, A. and Glanz, K. (1988). An Ecological Perspective on Health Promotion Programs. *Health Education Quarterly*, 15(4), pp.351–377.

McLoughlin, I., Garrety, K., Wilson, R., Dalley, A. and Yu, P. (2016). Doing Infrastructural Work: The Role of Boundary Objects in Health Information Infrastructure Projects. *Scandinavian Journal of Information Systems*, [online] 28(2). Available at: http://aisel.aisnet.org/sjis/vol28/iss2/2 [Accessed 16 Jul. 2021].

Mehtälä, M.A., Sääkslahti, A., Inkinen, M. and Poskiparta, M.E. (2014). A Socio-Ecological Approach to Physical Activity Interventions in Childcare: A Systematic Review. *International Journal of Behavioural Nutrition and Physical Activity*, 11(1), pp.22–33.

Melville-Richards, L.A. (2015). *Exploring and Explaining the Role of Boundary Objects in Implementation through the National Institute of Health Research's Collaborations for Leadership in Applied Health Research and Care (NIHR CLAHRCs)*. PhD. Bangor

University.

Mengis, J. (2007). Integrating Knowledge Through Communication - The Case of Experts and Decision Makers. In: *Proceedings of OLKC 2007 "Learning Fusion."* [online] Available at: https://warwick.ac.uk/fac/soc/wbs/conf/olkc/archive/olkc2/papers/mengis.pdf [Accessed 17 Jul. 2021].

Merriam, S. (1998). *Qualitative Research and Case Study Applications in Education*. San Francisco: Jossey-Bass.

Meyer, M. (2010). The Rise of the Knowledge Broker. *Science Communication*, 32(1), pp.118–127.

Miah, S.J., Gammack, J. and Hasan, N. (2017). Extending the Framework for Mobile Health Information Systems Research: A Content Analysis. *Information Systems*, 69, pp.1–24.

Michie, S. (2008). Designing and Implementing Behaviour Change Interventions to Improve Population Health. *Journal of Health Services Research & Policy*, 13(3), pp.64–69.

Michie, S. (2013). Behaviour Change Techniques and a Framework for Increasing Physical Activity. In: *ISBNPA Satellite Conference 2013*. Cambridge: University College London.

Michie, S. (2021). *BCT Taxonomy Online Training*. [online] BCT-Taxonomy v1. Available at: http://www.bct-taxonomy.com/ [Accessed 25 Nov. 2019].

Michie, S., Ashford, S., Sniehotta, F.F., Dombrowski, S.U., Bishop, A. and French, D.P. (2011). A Refined Taxonomy of Behaviour Change Techniques to Help People Change Their Physical Activity and Healthy Eating Behaviours: The CALO-RE Taxonomy. *Psychology & Health*, 26(11), pp.1479–1498.

Michie, S., Carey, R.N., Johnston, M., Rothman, A.J., de Bruin, M., Kelly, M.P. and Connell, L.E. (2018a). From Theory-Inspired to Theory-Based Interventions: A Protocol for Developing and Testing a Methodology for Linking Behaviour Change Techniques to Theoretical Mechanisms of Action. *Annals of Behavioural Medicine*, 52(6), pp.501–512.

Michie, S., Johnston, M., Francis, J., Hardeman, W. and Eccles, M. (2008). From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour Change Techniques. *Applied Psychology*, 57(4), pp.660–680.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M.P., Cane, J. and Wood, C.E. (2013). The Behaviour Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behaviour Change Interventions. *Annals of Behavioural Medicine*, 46(1), pp.81–95.

Michie, S., van Stralen, M.M. and West, R. (2011). The Behaviour Change Wheel: A New Method for Characterising and Designing Behaviour Change Interventions. *Implementation Science*, 6(1), pp.42–53.

Michie, S., West, R., Sheals, K. and Godinho, C.A. (2018b). Evaluating the Effectiveness of Behaviour Change Techniques in Health-Related Behaviour: A Scoping Review of Methods Used. *Translational Behavioural Medicine*, 8(2), pp.212–224.

Michie, S., Wood, C.E., Johnston, M., Abraham, C., Francis, J.J. and Hardeman, W. (2015). Behaviour Change Techniques: The Development and Evaluation of a Taxonomic Method for Reporting and Describing Behaviour Change Interventions (A Suite of Five Studies Involving Consensus Methods, Randomised Controlled Trials and Analysis of Qualitative Data). *Health Technology Assessment*, 19(99), pp.1–188.

Michie, S., Yardley, L., West, R., Patrick, K. and Greaves, F. (2017). Developing and Evaluating Digital Interventions to Promote Behaviour Change in Health and Health Care: Recommendations Resulting From an International Workshop. *J Med Internet Res*, 19(6), pp.1–13.

Middelweerd, A., Mollee, J.S., van der Wal, C.N., Brug, J. and te Velde, S.J. (2014). Apps to Promote Physical Activity Among Adults: A Review and Content Analysis. *International Journal of Behavioural Nutrition and Physical Activity*, 11(1), pp.97–105.

Middelweerd, A., te Velde, S.J., Mollee, J.S., Klein, M.C. and Brug, J. (2018). App-Based Intervention Combining Evidence-Based Behaviour Change Techniques with a Model-Based Reasoning System to Promote Physical Activity Among Young Adults (Active2Gether): Descriptive Study of the Development and Content. *JMIR Research Protocols*, 7(12), p.e185.

Miller, A.D. (2014). *Social Tools for Everyday Adolescent Health*. PhD. Georgia Institute of Technology.

Millington, B. (2014). Smartphone Apps and the Mobile Privatisation of Health and Fitness. *Critical Studies in Media Communication*, 31(5), pp.479–493.

Milne-Ives, M., Lam, C., De Cock, C., Van Velthoven, M.H. and Meinert, E. (2020). Mobile Apps for Health Behaviour Change in Physical Activity, Diet, Drug and Alcohol Use, and Mental Health: A Systematic Review. *JMIR mHealth and uHealth*, 8(3), pp.1–16.

Ministry of Health (2015). *Noncommunicable Diseases Policy 2015: Republic of Rwanda*. [online] Ministry of Health. Available at: https://www.moh.gov.rw/news-detail/ncds-policy-2015 [Accessed 15 Jul. 2021].

Mishra, A. and Dubey, D. (2013). A Comparative Study of Different Software Development Life Cycle Models in Different Scenarios. *International Journal of Advance Research in Computer Science and Management Studies*, 1(3), pp.64–69.

Mitchell, M., Lau, E., White, L. and Faulkner, G. (2020). Commercial App Use Linked with Sustained Physical Activity in Two Canadian Provinces: A 12-Month Quasi-Experimental Study. *International Journal of Behavioural Nutrition and Physical Activity*, 17(1).

Modave, F., Bian, J., Leavitt, T., Bromwell, J., Harris III, C. and Vincent, H. (2015). Low Quality of Free Coaching Apps With Respect to the American College of Sports Medicine Guidelines: A Review of Current Mobile Apps. *JMIR mHealth and uHealth*, 3(3), p.e77.

MoEngage and Apptopia (2020). *An In-depth Report on Global Mobile Consumer Trends, 2020*. [online] MoEngage and Apptopia, pp.1–46. Available at: https://www.moengage.com/blog/global-mobile-consumer-trends-2020/ [Accessed 16 Jul. 2021].

Mohajan, H. (2018). Qualitative Research Methodology in Social Sciences and Related Subjects. *Journal of Economic Development, Environment and People*, 7(1), pp.23–48.

Mohr, D.C., Schueller, S.M., Montague, E., Burns, M.N. and Rashidi, P. (2014). The Behavioural Intervention Technology Model: An Integrated Conceptual and Technological Framework for eHealth and mHealth Interventions. *Journal of Medical Internet Research*, 16(6), pp.1–16.

Mohr, D.C., Schueller, S.M., Riley, W.T., Brown, C.H., Cuijpers, P., Duan, N., Kwasny, M.J., Stiles-Shields, C. and Cheung, K. (2015). Trials of Intervention Principles: Evaluation Methods for Evolving Behavioural Intervention Technologies. *Journal of Medical Internet Research*, 17(7), p.e166.

Molina-Recio, G., Molina-Luque, R., Jiménez-García, A.M., Ventura-Puertos, P.E., Hernández-Reyes, A. and Romero-Saldaña, M. (2020). Proposal for the User-Centered Design Approach for Health Apps Based on Successful Experiences: Integrative Review. *JMIR mHealth and uHealth*, 8(4), p.e14376.

Moller, A.C., Merchant, G., Conroy, D.E., West, R., Hekler, E., Kugler, K.C. and Michie, S. (2017). Applying and Advancing Behaviour Change Theories and Techniques in the Context of a Digital Health Revolution: Proposals for more Effectively Realising Untapped Potential. *Journal of Behavioural Medicine*, 40(1), pp.85–98.

Monteiro-Guerra, F., Signorelli, G.R., Tadas, S., Zubiete, E., Romero, O., Fernandez-Luque, L. and Caulfield, B. (2020). A Personalised Physical Activity Coaching App for Breast Cancer Survivors: Design Process and Early Prototype Testing. *JMIR mHealth and uHealth*, 8(7), p.e17552.

Morenga, L., Pekepo, C., Corrigan, C., Matoe, L., Mules, R., Goodwin, D., Dymus, J., Tunks, M., Grey, J., Humphrey, G., Jull, A., Whittaker, R., Verbiest, M., Firestone, R. and Ni Mhurchu, C. (2018). Co-Designing an mHealth Tool in the New Zealand Māori Community with a "Kaupapa Māori" Approach. *AlterNative: An International Journal of Indigenous Peoples*, 14(1), pp.90–99.

Morley, L. and Cashell, A. (2017). Collaboration in Health Care. *Journal of Medical Imaging and Radiation Sciences*, [online] 48(2), pp.207–216. Available at: https://www.jmirs.org/article/S1939-8654(16)30117-5/pdf [Accessed 17 Jul. 2021].

Morowatisharifabad, M.A., Abdolkarimi, M., Asadpour, M., Fathollahi, M.S. and Balaee, P. (2018). The Predictive Effects of Protection Motivation Theory on Intention and Behaviour of Physical Activity in Patients with Type 2 Diabetes. *Open Access Macedonian Journal of Medical Sciences*, 6(4), pp.709–714.

Morris, J.N., Heady, J.A., Raffle, P.A.B., Roberts, C.G. and Parks, J.W. (1953). Coronary Heart-Disease and Physical Activity of Work. *The Lancet*, 262(6795), pp.1053–1057.

Morrison, L., Muller, I., Yardley, L. and Bradbury, K. (2018). The Person-Based Approach to Planning, Optimising, Evaluating and Implementing Behavioural Health Interventions. *The European Health Psychologist*, 20(3), pp.464–469.

Morse, J.M. and Mitcham, C. (2002). Exploring Qualitatively-Derived Concepts: Inductive—Deductive Pitfalls. *International Journal of Qualitative Methods*, 1(4), pp.28–35.

Mortari, L. (2015). Reflectivity in Research Practice: An Overview of Different Perspectives. *International Journal of Qualitative Methods*, [online] 14(5), pp.1–9. Available at: https://journals.sagepub.com/doi/full/10.1177/1609406915618045 [Accessed 17 Jul. 2021].

Morville, P. (2004). *User Experience Design*. [online] Semantic Studios. Available at: https://semanticstudios.com/user_experience_design/ [Accessed 16 Jul. 2021].

Mthoko, H. (2016). *Outcome and Impact Assessment in the Comprehensive Evaluation of Rural ICT Projects in Developing Countries*. PhD. Rhodes University.

Muchagata, J. and Ferreira, A. (2018). Translating GDPR into the mHealth Practice. In: *2018 International Carnahan Conference on Security Technology (ICCST)*. [online] Available at: https://ieeexplore.ieee.org/abstract/document/8585546 [Accessed 17 Jul. 2021].

Mueller, B. and Urbach, N. (2017). Understanding the Why, What, and How of Theories in IS Research. *Communications of the Association for Information Systems*, 41(1), pp.349–388.

Mummah, S.A., Robinson, T.N., King, A.C., Gardner, C.D. and Sutton, S. (2016). IDEAS (Integrate, Design, Assess, and Share): A Framework and Toolkit of Strategies for the Development of More Effective Digital Interventions to Change Health Behaviour. *Journal of Medical Internet Research*, 18(12), pp.1–14.

Munson, S. and Consolvo, S. (2012). Exploring Goal-setting, Rewards, Self-monitoring, and Sharing to Motivate Physical Activity. In: *Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare*. [online] Available at: https://ieeexplore.ieee.org/document/6240359 [Accessed 16 Jul. 2021].

Murray, E., Hekler, E.B., Andersson, G., Collins, L.M., Doherty, A., Hollis, C., Rivera, D.E.,

West, R. and Wyatt, J.C. (2016). Evaluating Digital Health Interventions: Key Questions and Approaches. *American journal of preventive medicine*, 51(5), pp.843–851.

Müssener, U., Löf, M., Bendtsen, P. and Bendtsen, M. (2020). Using Mobile Devices to Deliver Lifestyle Interventions Targeting At-Risk High School Students: Protocol for a Participatory Design Study. *JMIR Research Protocols*, 9(1), p.e14588.

Myers, M.D. and Venable, J.R. (2014). A Set of Ethical Principles for Design Science Research in Information Systems. *Information & Management*, 51(6), pp.801–809.

Naderifar, M., Goli, H. and Ghaljaie, F. (2017). Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. *Strides in Development of Medical Education*, 14(3).

Nagle, T., Doyle, C., Alhassan, I. and Sammon, D. (2020). The Research Method we Need or Deserve? A Literature Review of the Design Science Research Landscape. *OSF Preprints*, [online] pp.1–28. Available at: https://osf.io/yjbd7/ [Accessed 17 Jul. 2021].

Nagle, T., Ibrahim, C., Alhassan, I. and Sammon, D. (2020). *The Research Method we Need or Deserve? A Literature Review of the Design Science Research Landscape*. [online] OSF Preprints. Available at: https://doi.org/10.31219/osf.io/yjbd7 [Accessed 15 Jul. 2021].

Naik, R. and Kaneda, T. (2015). *Youth Are Key to Tackling Noncommunicable Diseases in Africa*. [online] PRB. Available at: https://www.prb.org/resources/youth-are-key-to-tackling-noncommunicable-diseases-in-africa/ [Accessed 15 Jul. 2021].

Nancarrow, S.A., Booth, A., Ariss, S., Smith, T., Enderby, P. and Roots, A. (2013). Ten Principles of Good Interdisciplinary Team Work. *Human Resources for Health*, 11(1).

National Institute for Health and Care Excellence (2014). *NICE Guideline: Behaviour Change: Individual Approaches PH49*. [online] NICE. Available at: https://www.nice.org.uk/guidance/PH49 [Accessed 16 Jul. 2021].

National Institute for Health and Care Excellence (2020). *Behaviour Change: Digital and Mobile Health Interventions (NG183)*. [online] NICE. Available at: https://www.nice.org.uk/guidance/ng183 [Accessed 16 Jul. 2021].

Nebeker, C. (2020). mHealth Research Applied to Regulated and Unregulated Behavioural

Health Sciences. *The Journal of Law, Medicine & Ethics*, 48(1), pp.49–59.

Ni Mhurchu, C., Morenga, L., Tupai-Firestone, R., Grey, J., Jiang, Y., Jull, A., Whittaker, R., Dobson, R., Dalhousie, S., Funaki, T., Hughes, E., Henry, A., Lyndon-Tonga, L., Pekepo, C., Penetito-Hemara, D., Tunks, M., Verbiest, M., Humphrey, G., Schumacher, J. and Goodwin, D. (2019). A Co-Designed mHealth Programme to Support Healthy Lifestyles in Māori and Pasifika Peoples in New Zealand (OL@-OR@): A Cluster-Randomised Controlled Trial. *Lancet Digital Health*, 1(6), pp.e298–e307.

Nicholas, J.C., Ntoumanis, N., Smith, B.J., Quested, E., Stamatakis, E. and Thøgersen-Ntoumani, C. (2021). Development and Feasibility of a Mobile Phone Application Designed to Support Physically Inactive Employees to Increase Walking. *BMC Medical Informatics and Decision Making*, 21(1), pp.1–16.

Nicolini, D., Mengis, J. and Swan, J. (2012). Understanding the Role of Objects in Cross-Disciplinary Collaboration. *Organisation Science*, 23(3), pp.612–629.

Norman, D. (2013). *The Design of Everyday Things (Revised and Expanded Edition)*. New York: Basics Books.

Norris, E. (2019). Behaviour Change Techniques on the Go: Launch of a New Version of the BCTTv1 App. *CBC Digi-Hub*. Available at: https://blogs.ucl.ac.uk/cbc-digi-hub-blog/2019/06/04/behaviour-change-techniques-on-the-go-launch-of-a-new-version-of-the-bcttv1-app/ [Accessed 16 Jul. 2021].

Nowell, L.S., Norris, J.M., White, D.E. and Moules, N.J. (2017). Thematic analysis: striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, 16(1), pp.1–13.

Nugent, R. (2015). *Benefits and Costs of the Non-Communicable Disease Targets for the Post-2015 Development Agenda*. [online] Disease Control Priorities. Available at: https://dcp-3.org/resources/benefits-and-costs-non-communicable-disease-targets-post-2015-development-agenda [Accessed 15 Jul. 2021].

Nunamaker, J.F., Chen, M. and Purdin, T.D.M. (1991). Systems Development in Information Systems Research. *Journal of Management Information Systems*, 7(3), pp.89–106.

Nuojua, S.K. (2017). *Effectiveness of Interventions to Promote Physical Activity in Overweight Adults in the Health Care Setting: A Systematic Review*. Masters. University of Jyväskylä.

NVivo (2021). *NVivo: Qualitative Data Analysis Software*. [online] QSR International. Available at: https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home [Accessed 17 Jul. 2021].

O'Cathain, A., Croot, L., Sworn, K., Duncan, E., Rousseau, N., Turner, K., Yardley, L. and Hoddinott, P. (2019). Taxonomy of Approaches to Developing Interventions to Improve Health: A Systematic Methods Overview. *Pilot and Feasibility Studies*, 5(1), pp.1–27.

O'Donnell, M.P. (2009). Definition of Health Promotion 2.0: Embracing Passion, Enhancing Motivation, Recognising Dynamic Balance, and Creating Opportunities. *American Journal of Health Promotion*, 24(1), p.iv.

O'Donnell, M.P. (2011). Reflections on the 25th Anniversary of Publishing the American Journal of Health Promotion: People, Scientific Progress, and Missteps. *American Journal of Health Promotion*, 25(4), pp.iv–xi.

O'Dwyer, T., Maguire, S., Mockler, D., Durcan, L. and Wilson, F. (2019). Behaviour Change Interventions Targeting Physical Activity in Adults with fibromyalgia: A Systematic Review. *Rheumatology International*, 39(5), pp.805–817.

O'Mahoney, J., Vincent, S. and Harley, B. (2018). Realist Studies of Oppression, Emancipation and Resistance. *Organisation*, 25(5), pp.575–584.

O'Reilly, P., Lee, S.H., O'Sullivan, M., Cullen, W., Kennedy, C. and MacFarlane, A. (2017). Assessing the Fcilitators and Barriers of Interdisciplinary Team Working in Primary Care Using Normalisation Process Theory: An Integrative Review. *PLOS ONE*, 12(5), p.e0177026.

Oduor, M., Alahäivälä, T. and Oinas-Kukkonen, H. (2014). Persuasive Software Design Patterns for Social Influence. *Personal and Ubiquitous Computing*, 18(7), pp.1689–1704.

Oehlberg, L. (2012). *Information Sharing Tools and Behaviour in Collaborative Human-*

*Centered Design Teams*. PhD. University of California.

Oinas-Kukkonen, H. and Harjumaa, M. (2009). Persuasive Systems Design: Key Issues, Process Model, and System Features. *Communications of the Association for Information Systems*, 24, pp.1–18.

Okesina, M. (2020). A Critical Review of the Relationship between Paradigm, Methodology, Design and Method in Research. *IOSR Journal of Research & Method in Education*, 10(3), pp.57–68.

Olejniczak, K. (2017). The Game of Knowledge Brokering. *American Journal of Evaluation*, 38(4), pp.554–576.

Olsen, B., Windfeld Lund, N., Ellingsen, G. and Hartvigsen, G. (2012). Document Theory for the Design of Socio-Technical Systems. *Journal of Documentation*, 68(1), pp.100–126.

Orlikowski, W.J. (2000). Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organisations. *Organisation Science*, [online] 11(4), pp.404–428. Available at: https://www.jstor.org/stable/2640412 [Accessed 16 Jul. 2021].

Orlikowski, W.J. (2007). Sociomaterial Practices: Exploring Technology at Work. *Organisation Studies*, 28(9), pp.1435–1448.

Osah, U.J. (2017). *A Systems Thinking Approach to e-Government Strategy Formulation for Water Service Delivery in South African Local Municipalities*. PhD. Rhodes University.

Othman, M. k, Ugap, N. and Rahman, N.D. (2019). Play4fit: Enhancing Users' Engagement with Smartphone Health And Fitness Application Using Gamification Concept. *International Journal of Scientific & Technology Research*, 8(12), pp.676–681.

Ouma, S. (2013). *mHealth User Experience Framework for the Public Healthcare Sector*. PhD. Nelson Mandela University.

Oyebode, O., Ndulue, C., Alhasani, M. and Orji, R. (2020). Persuasive Mobile Apps for Health and Wellness: A Comparative Systematic Review. In: *Persuasive Technology. Designing for Future Change*. [online] pp.163–181. Available at: https://link.springer.com/chapter/10.1007%2F978-3-030-45712-9_13 [Accessed 17 Jul. 2021].

Paavola, S. (2006). *On the Origins of Ideas: An Abductivist Approach to Discovery*. PhD. University of Helsinki.

Paffenbarger, R.S., Blair, S.N. and Lee, I. (2001). A History of Physical Activity, Cardiovascular Health and Longevity: The Scientific Contributions of Jeremy N Morris, DSc, DPH, FRCP. *International Journal of Epidemiology*, 30(5), pp.1184–1192.

Paffenbarger, R.S., Hyde, R.T., Wing, A.L., Lee, I., Jung, D.L. and Kampert, J.B. (1993). The Association of Changes in Physical-Activity Level and Other Lifestyle Characteristics with Mortality among Men. *New England Journal of Medicine*, 328(8), pp.538–545.

Pagliari, C. (2007). Design and Evaluation in eHealth: Challenges and Implications for an Interdisciplinary Field. *Journal of Medical Internet Research*, 9(2), p.e15.

Palmer, M., Sutherland, J., Barnard, S., Wynne, A., Rezel, E., Doel, A., Grigsby-Duffy, L., Edwards, S., Russell, S., Hotopf, E., Perel, P. and Free, C. (2018). The Effectiveness of Smoking Cessation, Physical Activity/Diet and Alcohol Reduction Interventions Delivered by Mobile Phones for the Prevention of Noncommunicable Diseases: A Systematic Review of Randomised Controlled Trials. *PLOS ONE*, 13(1), pp.1–71.

Papas, N., O'Keefe, R.M. and Seltsikas, P. (2012). The Action Research vs Design Science Debate: Reflections from an Intervention in eGovernment. *European Journal of Information Systems*, 21(2), pp.147–159.

Park, J. (2018). Designer-User Interaction without Actual Users: A Lesson from a Field Study. *Asia Pacific Journal of Information Systems*, 28(3), pp.220–239.

Parker, A.G., Markulev, C., Rickwood, D.J., Mackinnon, A., Purcell, R., Alvarez-Jimenez, M., Yung, A.R., McGorry, P., Hetrick, S.E. and Jorm, A. (2019). Improving Mood with Physical ACTivity (IMPACT) Trial: A Cluster Randomised Controlled Trial to Determine the Effectiveness of a Brief Physical Activity Behaviour Change Intervention on Depressive Symptoms in Young People, Compared with Psychoeducation, in Addition to Routine Clinical Care Within Youth Mental Health Services — A Protocol Study. *BMJ Open*, 9(10), p.e034002.

Parry, C.D., Patra, J. and Rehm, J. (2011). Alcohol Consumption and Noncommunicable Diseases: Epidemiology and Policy Implications. *Addiction*, 106(10), pp.1718–1724.

Paul, L., Brewster, S., Wyke, S., McFadyen, A.K., Sattar, N., Gill, J.M., Dybus, A. and Gray, C.M. (2017). Increasing Physical Activity in Older Adults Using STARFISH, An Interactive Smartphone Application (App); A Pilot Study. *Journal of Rehabilitation and Assistive Technologies Engineering*, 4, pp.1–10.

Pawlowski and Robey (2004). Bridging User Organisations: Knowledge Brokering and the Work of Information Technology Professionals. *MIS Quarterly*, 28(4), pp.645–672.

Payne, H.E., Lister, C., West, J.H. and Bernhardt, J.M. (2015). Behavioural Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature. *JMIR mHealth and uHealth*, 3(1), pp.1–9.

Peffers, K., Rothenberger, M., Tuunanen, T. and Vaezi, R. (2012). Design Science Research Evaluation. In: *Design Science Research in Information Systems. Advances in Theory and Practice*. [online] pp.398–410. Available at: https://link.springer.com/chapter/10.1007/978-3-642-29863-9_29 [Accessed 17 Jul. 2021].

Peffers, K., Tuunanen, T. and Niehaves, B. (2018). Design Science Research Genres: Introduction to the Special Issue on Exemplars and Criteria for Applicable Design Science Research. *European Journal of Information Systems*, 27(2), pp.129–139.

Peffers, K., Tuunanen, T., Gengler, C.E., Rossi, M., Hui, W., Virtanen, V. and Bragge, J. (2006). Design Science Research Process: A Model for Producing and Presenting Information Systems Research. In: *Proceedings of the First International Conference on Design Science Research in Information Systems and Technology*. [online] pp.83–106. Available at: https://arxiv.org/abs/2006.02763 [Accessed 15 Jul. 2021].

Peffers, K., Tuunanen, T., Rothenberger, M.A. and Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, 24(3), pp.45–77.

Peirce, C.S. (1931). *The Collected Papers of Charles Sanders Peirce, Vol. I: The Principles of Philosophy*. Cambridge: Harvard University Press.

Peirce, C.S. (1932). *The Collected Papers of Charles Sanders Peirce, Vol. II: Elements of Logic*. Cambridge: Harvard University Press.

Peirce, C.S. (1933). *The Collected Papers of Charles Sanders Peirce, Vol. IV: The Simplest Mathematics*. Cambridge: Harvard University Press.

Peirce, C.S. (1934). *The Collected Papers of Charles Sanders Peirce, Vol. V: Pragmatism and Pragmaticism*. Cambridge: Harvard University Press.

Peirce, C.S. (1935). *The Collected Papers of Charles Sanders Peirce, Vol. VI: Scientific Metaphysics*. Cambridge: Harvard University Press.

Peirce, C.S. (1958). *The Collected Papers of Charles Sanders Peirce, Vol. VII: Science and Philosophy*. Cambridge: Harvard University Press.

Peiris, D., Miranda, J.J. and Mohr, D.C. (2018). Going Beyond Killer Apps: Building a Better mHealth Evidence Base. *BMJ Global Health*, 3(1), pp.1–3.

Perski, O., Blandford, A., West, R. and Michie, S. (2017). Conceptualising Engagement with Digital Behaviour Change Interventions: A Systematic Review Using Principles from Critical Interpretive Synthesis. *Translational Behavioural Medicine*, 7(2), pp.254–267.

Petersen, C., Adams, S.A. and DeMuro, P.R. (2015). mHealth: Don't Forget All the Stakeholders in the Business Case. *Medicine 2.0*, 4(2), pp.1–5.

Petersen, J.M., Prichard, I. and Kemps, E. (2019). A Comparison of Physical Activity Mobile Apps With and Without Existing Web-Based Social Networking Platforms: Systematic Review. *Journal of Medical Internet Research*, 21(8), p.e12687.

Pfeiffer, D. (2008). *Semantic Business Process Analysis: Building Block-Based Construction of Automatically Analysable Business Process Models*. PhD. University of Münster.

Pfeiffer, D. and Niehaves, B. (2005). Evaluation of Conceptual Models - A Structuralist Approach. In: *ECIS 2005 Proceedings*. [online] Available at: http://aisel.aisnet.org/ecis2005/43 [Accessed 17 Jul. 2021].

Pfister, R.A. and Eppler, M.J. (2012). The Benefits of Sketching for Knowledge Management. *Journal of Knowledge Management*, 16(2), pp.372–382.

Pikas, E., Koskela, L., Tredal, N., Knotten, V. and Bølviken, T. (2018). The Dual Nature of Design Management. In: *26th Annual Conference of the International Group for Lean*

*Construction*. [online] pp.647–657. Available at: https://pure.hud.ac.uk/en/publications/the-dual-nature-of-design-management [Accessed 17 Jul. 2021].

Plasker, E.D.C. (2010). *The 100 Year Lifestyle Workout: The High Energy Fitness Program for Living Your Peak Throughout Your Lifetime*. Guilford: Rowman & Littlefield.

Plotnikoff, R.C. and Trinh, L. (2010). Protection Motivation Theory. *Exercise and Sport Sciences Reviews*, 38(2), pp.91–98.

Polgar, S. (1962). Health and Human Behaviour: Areas of Interest Common to the Social and Medical Sciences. *Current Anthropology*, 3(2), pp.159–205.

Pollack, S. *Out of Africa*. (1985). [Film] Universal Pictures.

Ponnada, A., Thapa-Chhetry, B., Manjourides, J. and Intille, S. (2021). Measuring Criterion Validity of Microinteraction Ecological Momentary Assessment (Micro-EMA): Exploratory Pilot Study with Physical Activity Measurement. *JMIR mHealth and uHealth*, 9(3), p.e23391.

Poppe, L., De Bourdeaudhuij, I., Verloigne, M., Shadid, S., Van Cauwenberg, J., Compernolle, S. and Crombez, G. (2019). Efficacy of a Self-Regulation–Based Electronic and Mobile Health Intervention Targeting an Active Lifestyle in Adults Having Type 2 Diabetes and in Adults Aged 50 Years or Older: Two Randomised Controlled Trials. *Journal of Medical Internet Research*, 21(8), p.e13363.

Porter, S.J. and Hook, D.W. (2020). *How COVID-19 is Changing Research Culture: Landscape Trends and Cultural Changes in the Global Research System*. London: Digital Science.

Powell, T.C. (2001). Competitive Advantage: Logical and Philosophical Considerations. *Strategic Management Journal*, 22(9), pp.875–888.

Prat, N., Comyn-Wattiau, I. and Akoka, J. (2014). Artifact Evaluation in Information Systems Design-Science Research - A Holistic View. In: *PACIS 2014*. [online] pp.1–16. Available at: https://aisel.aisnet.org/pacis2014/23/ [Accessed 15 Jul. 2021].

Prestwich, A., Sniehotta, F.F., Whittington, C., Dombrowski, S.U., Rogers, L. and Michie, S.

(2014). Does Theory Influence the Effectiveness of Health Behaviour Interventions? Meta-Analysis. *Health Psychology*, 33(5), pp.465–474.

Prestwich, A., Webb, T.L. and Conner, M. (2015). Using Theory to Develop and Test Interventions to Promote Changes in Health Behaviour: Evidence, Issues, and Recommendations. *Current Opinion in Psychology*, 5, pp.1–5.

Pries-Heje, J., Baskerville, R. and Venable, J. (2008). Strategies for Design Science Research Evaluation. In: *ECIS 2008 Proceedings*. [online] Available at: http://aisel.aisnet.org/ecis2008/87 [Accessed 17 Jul. 2021].

Prochaska, J.J., Spring, B. and Nigg, C.R. (2008). Multiple Health Behaviour Change Research: An Introduction and Overview. *Preventive Medicine*, 46(3), pp.181–188.

Prochaska, J.O. and DiClemente, C.C. (1982). Transtheoretical therapy: Toward a More Integrative Model of Change. *Psychotherapy: Theory, Research & Practice*, 19(3), pp.276–288.

Punton, M. (2016). *How Can Capacity Development Promote Evidence-Informed Policy Making: Literature Review for the Building Capacity to Use Research Evidence (BCURE) Programme*. Hove: ITAD.

Rabbi, M., Pfammatter, A., Zhang, M., Spring, B. and Choudhury, T. (2015). Automated Personalised Feedback for Physical Activity and Dietary Behaviour Change With Mobile Phones: A Randomised Controlled Trial on Adults. *JMIR mHealth and uHealth*, 3(2), p.e42.

Raingruber, B. (2017). *Contemporary Health Promotion in Nursing Practice*. Burlington, MA: Jones & Bartlett Publishers.

Rakevičius, E. (2016). *The Process of Knowledge Integration A Case Study of a Change Project*. Masters. Linköping University.

Ralph, P. and Wand, Y. (2009). A Proposal for a Formal Definition of the Design Concept. *Lecture Notes in Business Information Processing*, 14, pp.103–136.

Ramdani, B., Duan, B. and Berrou, I. (2020). Exploring the Determinants of Mobile Health Adoption by Hospitals in China. *JMIR Medical Informatics*, 8(7).

Ramos-Pedersen, T.R. (2020). *The Importance of Building Trust in Digital Co-Design*. Masters. Malmo University.

Recio-Rodriguez, J.I., Agudo-Conde, C., Martin-Cantera, C., González-Viejo, M.N., Fernandez-Alonso, M.C., Arietaleanizbeaskoa, M.S., Schmolling-Guinovart, Y., Maderuelo-Fernandez, J.A., Rodriguez-Sanchez, E., Gomez-Marcos, M.A., Garcia-Ortiz, L. and Investigators, E. (2016). Short-Term Effectiveness of a Mobile Phone App for Increasing Physical Activity and Adherence to the Mediterranean Diet in Primary Care: A Randomised Controlled Trial (EVIDENT II Study). *Journal of Medical Internet Research*, 18(12), p.e331.

Recio-Rodriguez, J.I., Gómez-Marcos, M.A., Agudo-Conde, C., Ramirez, I., Gonzalez-Viejo, N., Gomez-Arranz, A., Salcedo-Aguilar, F., Rodriguez-Sanchez, E., Alonso-Domínguez, R., Sánchez-Aguadero, N., Gonzalez-Sanchez, J. and Garcia-Ortiz, L. (2018). EVIDENT 3 Study: A Randomised, Controlled Clinical Trial to Reduce Inactivity and Caloric Intake in Sedentary and Overweight or Obese People Using a Smartphone Application. *Medicine*, 97(2), p.e9633.

Reports and Data (2020). *Mobile Health (mHealth) Market Size, Share, Analysis by Platform, by Application (Education and Awareness, Disease and Epidemic Outbreak Tracking, Communication and Training, Diagnostics and Treatment), and by End Use, Forecasts To 2027*. [online] Reports and Data. Available at: https://www.reportsanddata.com/report-detail/mobile-health-mhealth-market [Accessed 16 Jul. 2021].

Reymen, I., Kroes, P. and Basten, T. (2002). Modelling the Role of the Design Context in the Design Process: A Domain-Independent Approach. In: D. Durling and J. Shackleton, eds., *Common Ground, Proceedings of Design Research Society International Conference 2002*. [online] Staffordshire: Staffordshire University Press, pp.917–927. Available at: https://research.utwente.nl/en/publications/modelling-the-role-of-the-design-context-in-the-design-process-a- [Accessed 17 Jul. 2021].

Reymen, I.M.M.J., Hammer, D.K., Kroes, P.A., van Aken, J.E., Dorst, C.H., Bax, M.F.T. and Basten, T. (2006). A Domain-Independent Descriptive Design Model and its Application to Structured Reflection on Design Processes. *Research in Engineering Design*, 16(4), pp.147–173.

Rhinow, H., Köppen, E. and Meinenl, C. (2012). Design Prototypes as Boundary Objects in Innovation Processes. In: *Proceedings of the 2012 International Conference on Design Research Society (DRS 2012)*. [online] Available at: https://www.semanticscholar.org/paper/Design-Prototypes-as-Boundary-Objects-in-Innovation-Rhinow-K%C3%B6ppen/29c7f9d6f56e95036cf1499adffe903eed284e30 [Accessed 17 Jul. 2021].

Rhodes, R.E. and Yao, C.A. (2015). Models Accounting for Intention-Behaviour Discordance in the Physical Activity Domain: A User's Guide, Content Overview, and Review of Current Evidence. *International Journal of Behavioural Nutrition and Physical Activity*, 12(1), pp.9–23.

Rhodes, R.E., Boudreau, P., Josefsson, K.W. and Ivarsson, A. (2020). Mediators of Physical Activity Behaviour Change Interventions Among Adults: A Systematic Review and Meta-Analysis. *Health Psychology Review*, 15(2), pp.272–286.

Rhodes, R.E., Janssen, I., Bredin, S.S.D., Warburton, D.E.R. and Bauman, A. (2017). Physical Activity: Health Impact, Prevalence, Correlates and Interventions. *Psychology & Health*, 32(8), pp.942–975.

Rhodes, R.E., Kaushal, N. and Quinlan, A. (2016). Is Physical Activity a Part of Who I Am? A Review and Meta-Analysis of Identity, Schema and Physical Activity. *Health Psychology Review*, 10(2), pp.204–225.

Rhodes, R.E., McEwan, D. and Rebar, A.L. (2019). Theories of Physical Activity Behaviour Change: A History and Synthesis of Approaches. *Psychology of Sport and Exercise*, 42, pp.100–109.

Richard, L., Gauvin, L. and Raine, K. (2011). Ecological Models Revisited: Their Uses and Evolution in Health Promotion Over Two Decades. *Annual Review of Public Health*, 32(1), pp.307–326.

Riley, W.T., Oh, A., Aklin, W.M. and Wolff-Hughes, D.L. (2019). National Institutes of Health Support of Digital Health Behaviour Research. *Health Education & Behaviour*, 46(2S), pp.12S19S.

Rittel, H.W.J. and Webber, M.M. (1973). Dilemmas in a General Theory of Planning. *Policy*

*Sciences*, 4(2), pp.155–169.

Robert, L.P., Dennis, A.R. and Ahuja, M.K. (2008). Social Capital and Knowledge Integration in Digitally Enabled Teams. *Information Systems Research*, 19(3), pp.314–334.

Roberts, A.E., Davenport, T.A., Wong, T., Moon, H.W., Hickie, I.B. and LaMonica, H.M. (2021). Evaluating the Quality and Safety of Health-Related Apps and e-Tools: Adapting the Mobile App Rating Scale and Developing a Quality Assurance Protocol. *Internet Interventions*, 24, p.100379.

Roberts, J. (2006). Limits to Communities of Practice. *Journal of Management Studies*, 43(3), pp.623–639.

Robinson, S. (2021). *Priorities for Health Promotion and Public Health: Explaining the Evidence for Disease Prevention and Health Promotion*. London: Routledge.

Rogers, R.W. (1975). A Protection Motivation Theory of Fear Appeals and Attitude Change. *The Journal of Psychology*, 91(1), pp.93–114.

Rogers, R.W. (1983). Cognitive and Psychological Process in Fear Appeals and Attitude Change: A Revised Theory of Protection Motivation. In: J. Cacioppo and R. Petty, eds., *Basic Social Psychophysiological Research*. New York: Guilford Press, pp.153–177.

Roller, M.R. and Lavrakas, P.J. (2015). *Applied Qualitative Research Design: A Total Quality Framework Approach*. London: The Guilford Press.

Romeo, A., Edney, S., Plotnikoff, R., Curtis, R., Ryan, J., Sanders, I., Crozier, A. and Maher, C. (2019). Can Smartphone Apps Increase Physical Activity? Systematic Review and Meta-Analysis. *Journal of Medical Internet Research*, 21(3), p.e12053.

Rosenkranz, H., Vranešić, H. and Holten, R. (2014). Boundary Interactions and Motors of Change in Requirements Elicitation: A Dynamic Perspective on Knowledge Sharing. *Journal of the Association for Information Systems*, 15(6), pp.306–345.

Rousseau, N., Turner, K.M., Duncan, E., O'Cathain, A., Croot, L., Yardley, L. and Hoddinott, P. (2019). Attending to Design When Developing Complex Health Interventions: A Qualitative Interview Study with Intervention Developers and Associated Stakeholders. *PLOS ONE*, 14(10), pp.1–20.

Rubinelli, S. and Diviani, N. (2020). The Bases of Targeting Behaviour in Health Promotion and Disease Prevention. *Patient Education and Counseling*, 103, pp.2395–2399.

Ruegsegger, G.N. and Booth, F.W. (2017). Health Benefits of Exercise. *Cold Spring Harbor Perspectives in Medicine*, 8(7), p.a029694.

Rushmer, R., Ward, V., Nguyen, T. and Kuchenmüller, T. (2019). Knowledge Translation: Key Concepts, Terms and Activities. In: M. Verschuuren and H. van Oers, eds., *Population Health Monitoring*. pp.127–150.

Ruthig, J.C. (2016). Health Risk Perceptions and Exercise in Older Adulthood. *Journal of Applied Gerontology*, 35(9), pp.939–959.

Sallis, J.F., Cervero, R.B., Ascher, W., Henderson, K.A., Kraft, M.K. and Kerr, J. (2006). An Ecological Approach to Creating Active Living Communities. *Annual Review of Public Health*, 27(1), pp.297–322.

Salwen-Deremer, J.K., Khan, A.S., Martin, S.S., Holloway, B.M. and Coughlin, J.W. (2020). Incorporating Health Behaviour Theory into mHealth: an Examination of Weight Loss, Dietary, and Physical Activity Interventions. *Journal of Technology in Behavioural Science*, 5(1), pp.51–60.

Samdal, G.B., Eide, G.E., Barth, T., Williams, G. and Meland, E. (2017). Effective Behaviour Change Techniques for Physical Activity and Healthy Eating in Overweight and Obese Adults; Systematic Review and Meta-Regression Analyses. *International Journal of Behavioural Nutrition and Physical Activity*, 14(1), pp.1–14.

Sandborg, J., Henriksson, P., Larsen, E., Lindqvist, A.K., Rutberg, S., Söderström, E., Maddison, R. and Löf, M. (2021). Participants' Engagement and Satisfaction With a Smartphone App Intended to Support Healthy Weight Gain, Diet, and Physical Activity During Pregnancy: Qualitative Study Within the HealthyMoms Trial. *JMIR mHealth and uHealth*, 9(3), p.e26159.

Sander, V., Nolwenn, M. and Céline, M. (2019). Exploring How Boundary Objects Can Support Multidisciplinary Design and Science Collaboration. In: *International Association of Societies of Design Research Conference 2019*. [online] Research Gate. Available at:

https://www.researchgate.net/publication/335699791_Exploring_How_Boundary_Objects_Can_Support_Multidisciplinary_Design_and_Science_Collaboration [Accessed 17 Jul. 2021].

Sankowska, A. and Söderlund, J. (2015). Trust, Reflexivity and Knowledge Integration: Toward a Conceptual Framework Concerning Mobile Engineers. *Human Relations*, 68(6), pp.973–1000.

Saparamadu, A.A.D.N.S., Fernando, P., Zeng, P., Teo, W.M.H., Goh, X.T.A., Lee, J. and Lam, C.W., Leslie (2021). A User-Centered Design Process of an mHealth Application for Health Professionals: A Case Stud. *JMIR mHealth and uHealth*, 9(3).

Saracci, R. (1997). The World Health Organisation Needs to Reconsider its Definition of Health. *BMJ*, 314(7091), pp.1409–1410.

Saran, T., Owoc, J. and Bojar, I. (2018). Use of the IPAQ Questionnaire in the Form of a Mobile Application in Monitoring Physical Activity of Patients with Cardiovascular Diseases. *Annals of Agricultural and Environmental Medicine*, 25(3), pp.395–402.

Saunders, M., Lewis, P. and Thornhill, A. (2016). *Research Methods for Business Students*. 7th ed. Harlow, Munich: Pearson.

Scandurra, I., Hägglund, M. and Koch, S. (2008a). Application of the Multi-Disciplinary Thematic Seminar Method in Two Homecare Cases - A Comparative Study. *Studies in Health Technology and Informatics*, 136, pp.597–602.

Scandurra, I., Hägglund, M. and Koch, S. (2008b). From User Needs to System Specifications: Multi-Disciplinary Thematic Seminars as a Collaborative Design Method for Development of Health Information Systems. *Journal of Biomedical Informatics*, 41(4), pp.557–569.

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., Gelaude, D., Mosley, J.P. and Travers, J. (2016). A User-Centered Model for Designing Consumer Mobile Health (mHealth) Applications (Apps). *Journal of Biomedical Informatics*, 60, pp.243–251.

Schneiderhan, E. (2016). Theorising Resistance. *The British Journal of Sociology*, 67(1),

pp.43–49.

Schoeppe, S., Alley, S., Rebar, A.L., Hayman, M., Bray, N.A., Van Lippevelde, W., Gnam, J.P., Bachert, P., Direito, A. and Vandelanotte, C. (2017). Apps to Improve Diet, Physical Activity and Sedentary Behaviour in Children and Adolescents: A Review of Quality, Features and Behaviour Change Techniques. *The international journal of Behavioural nutrition and physical activity*, 14(1), p.83.

Schölmerich, V.L.N. and Kawachi, I. (2016). Translating the Socio-Ecological Perspective into Multilevel Interventions. *Health Education & Behaviour*, 43(1), pp.17–20.

Schroé, H., Van Dyck, D., De Paepe, A., Poppe, L., Loh, W.W., Verloigne, M., Loeys, T., De Bourdeaudhuij, I. and Crombez, G. (2020). Which Behaviour Change Techniques are Effective to Promote Physical Activity and Reduce Sedentary Behaviour in Adults: A Factorial Randomised Trial of an e- and m-Health Intervention. *International Journal of Behavioural Nutrition and Physical Activity*, 17(1), pp.127–143.

Schütte, R. and Rotthowe, T. (1998). The Guidelines of Modeling – An Approach to Enhance the Quality in Information Models. In: *Conceptual Modeling – ER '98*. [online] pp.240–254. Available at: https://link.springer.com/chapter/10.1007/978-3-540-49524-6_20 [Accessed 17 Jul. 2021].

Schwarzer, R. (1992). Self-Efficacy in the Adoption and Maintenance of Health Behaviours: Theoretical Approaches and a New Model. In: *Self-Efficacy: Thought Control of Action*. London: Hemisphere Publishing Corp, pp.217–243.

Schwarzer, R. (2008). Modeling Health Behaviour Change: How to Predict and Modify the Adoption and Maintenance of Health Behaviours. *Applied Psychology*, 57(1), pp.1–29.

Seeberg, J. and Meinert, L. (2015). Can Epidemics be Noncommunicable? Reflections on the Spread of "Noncommunicable" Diseases. *Medicine Anthropology Theory*, 2(2), pp.54–71.

Seffah, A., Gulliksen, J. and Desmarais, M. (2005). *Human-Centered Software Engineering - Integrating Usability in the Software Development Lifecycle*. Amsterdam: Springer Netherlands.

Seidman, I. (2006). *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*. 3rd ed. New York: Teachers College Press.

Seligman, M.E.P. (2012). *Flourish: A Visionary New Understanding of Happiness and Well-Being*. New York: Atria Books.

Sellak, H. and Grobler, M. (2020). mHealth4U: Designing for Health and Wellbeing Self-Management. In: *Proceedings of the 35th IEEE/ACM International Conference on Automated Software Engineering Workshops*. [online] Available at: https://dl.acm.org/doi/10.1145/3417113.3422179 [Accessed 16 Jul. 2021].

Sensor Tower (2020). Health & Fitness App Adoption Up Record 47% So Far in Q2 2020. *Sensor Tower Blog*. Available at: https://sensortower.com/blog/health-and-fitness-app-record-download-growth [Accessed 16 Jul. 2021].

Shahsavari, H., Matourypour, P., Ghiyasvandian, S. and Nejad, M.R.G. (2020). Medical Research Council Framework for Development and Evaluation of Complex Interventions: A Comprehensive Guidance. *Journal of Education and Health Promotion*, 9(1), p.88.

Shannon, C. and Weaver, W. (1949). *The Mathematical Theory of Communications*. Urbana, IL: University of Illinois Press.

Shapiro, R.M. (2020). *Boundaries and Infomediaries: A Qualitative Study of the Information Practices of Community Health Workers*. PhD. University of Kentucky.

Shepherd, D.A. and Sutcliffe, K.M. (2011). Inductive Top-Down Theorising: A Source of New Theories of Organisation. *The Academy of Management Review*, 36(2), pp.361–380.

Sherwood, N.E. and Jeffery, R.W. (2000). The Behavioural Determinants of Exericse: Implications for Physical Activity Interventions. *Annual Review of Nutrition*, 20(1), pp.21–44.

Shilton, T., Sparks, M., McQueen, D., Lamarre, M.C. and Jackson, S. (2011). Proposal for New Definition of Health. *BMJ*, 343(d5359), pp.1–1.

Short, C.E., DeSmet, A., Woods, C., Williams, S.L., Maher, C., Middelweerd, A., Müller, A.M., Wark, P.A., Vandelanotte, C., Poppe, L., Hingle, M.D. and Crutzen, R. (2018).

Measuring Engagement in eHealth and mHealth Behaviour Change Interventions: Viewpoint of Methodologies. *Journal of Medical Internet Research*, 20(11), p.e292.

Simeon, R., Dewidar, O., Trawin, J., Duench, S., Manson, H., Pardo Pardo, J., Petkovic, J., Hatcher-Roberts, J., Tugwell, P., Yoganathan, M., Presseau, J. and Welch, V. (2019). Behaviour Change Techniques Included in Reports of Social Media Interventions for Promoting Health Behaviours in Adults: A Study within a Review. *Journal of Medical Internet Research*, 22(6), pp.1–16.

Simmich, J., Mandrusiak, A., Smith, S.T., Hartley, N. and Russell, T.G. (2021). A Co-Designed Active Video Game for Physical Activity Promotion in People with COPD: Pilot Trial. *JMIR Serious Games*, 9(1), pp.1–30.

Simon, H.A. (1996). *The Sciences of the Artificial*. 3rd ed. Cambridge: MIT Press.

Simons, D., De Bourdeaudhuij, I., Clarys, P., De Cocker, K., Vandelanotte, C. and Deforche, B. (2018). A Smartphone App to Promote an Active Lifestyle in Lower-Educated Working Young Adults: Development, Usability, Acceptability, and Feasibility Study. *JMIR mHealth and uHealth*, 6(2), p.e44.

Skype (2021). *Skype*. [online] Skype. Available at: https://www.skype.com/en/ [Accessed 17 Jul. 2021].

Smith, A., de Salas, K., Lewis, I. and Schüz, B. (2017). Developing Smartphone Apps for Behavioural Studies: The AlcoRisk App Case Study. *Journal of Biomedical Informatics*, 72, pp.108–119.

Smith, A., de Salas, K., Schüz, B., Ferguson, S.G. and Lewis, I. (2016). mHealth Intervention Design: Creating mHealth Interventions for Behaviour Change. In: *Proceedings of the 28th Australian Conference on Computer-Human Interaction - OzCHI '16*. [online] pp.1–6. Available at: https://www.hindawi.com/journals/ecam/2014/561320/ [Accessed 16 Jul. 2021].

Smith, R., O'Grady, L. and Jadad, A.R. (2009). In search of health. *Journal of Evaluation in Clinical Practice*, 15(4), pp.743–744.

Smith, S.D. (1990). The Pursuit of Pragmatism. *The Yale Law Journal*, 100(2), pp.409–449.

Sniehotta, F.F., Araújo-Soares, V., Brown, J., Kelly, M.P., Michie, S. and West, R. (2017). Complex Systems and Individual-Level Approaches to Population Health: A False Dichotomy? *The Lancet Public Health*, 2(9), pp.e396–e397.

Sohaib Aslam, A., van Luenen, S., Aslam, S., van Bodegom, D. and Chavannes, N.H. (2020). A Systematic Review on the Use of mHealth to Increase Physical Activity in Older People. *Clinical eHealth*, 3, pp.31–39.

Sporrel, K., Nibbeling, N., Wang, S., Ettema, D. and Simons, M. (2021). Unraveling mHealth Exercise Interventions for Adults: A Scoping Review on the Implementations and Designs of Persuasive Strategies. *JMIR mHealth and uHealth*, 9(1), pp.1–19.

Stange, K. (2017). *Knowledge Production at Boundaries: An inquiry into Collaborations to Make Management Plans for European Fisheries*. PhD. Wageningen University.

Stange, K.C., Breslau, E.S., Dietrich, A.J. and Glasgow, R.E. (2012). State-of-the-Art and Future Directions in Multilevel Interventions Across the Cancer Control Continuum. *JNCI Monographs*, 2012(44), pp.20–31.

Stanley, E.H. (1873). *A Warning - Exercise and Illness - 14th Earl of Derby - Edward H. Stanley (English Political Leader)*. [Speech] *BMJ: British Medical Journal*, Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC555874/ [Accessed 18 Jul. 2021].

Stanley, R.M., Ridley, K., Olds, T.S. and Dollman, J. (2014). Increasing Specificity of Correlate Research: Exploring Correlates of Children's Lunchtime and After-School Physical Activity. *PLOS ONE*, 9(5), p.e96460.

Star, S.L. (1999). The Ethnography of Infrastructure. *American Behavioural Scientist*, 43(3), pp.377–391.

Star, S.L. (2010). This is Not a Boundary Object: Reflections on the Origin of a Concept. *Science, Technology, & Human Values*, 35(5), pp.601–617.

Star, S.L. and Griesemer, J.R. (1989). Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, 19(3), pp.387–420.

Star, S.L., Bowker, G.C. and Neumann, L.J. (2003). Transparency beyond the Individual Level

of Scale: Convergence between Information Artifacts and Communities of Practice. In: A. Peterson Bishop, N.A. Van House and B.P. Buttenfield, eds., *Digital Library Use: Social Practice in Design and Evaluation*. London: MIT Press, pp.241–270.

Statista (2021a). *Leading Health and Fitness Apps in the Google Play Store Worldwide in September 2020, by Revenue (in US Dollars)*. [online] Statista. Available at: https://www.statista.com/statistics/695697/top-android-health-apps-in-google-play-by-revenue/ [Accessed 11 Jan. 2021].

Statista (2021b). *Number of Smartphone Users Worldwide from 2016 to 2021 (in Billions)*. [online] Statista. Available at: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide [Accessed 11 Jan. 2021].

Stawarz, K., Cox, A.L. and Blandford, A. (2015). Beyond Self-Tracking and Reminders: Designing Smartphone Apps That Support Habit Formation. In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. [online] pp.1–10. Available at: https://dl.acm.org/doi/10.1145/2702123.2702230 [Accessed 16 Jul. 2021].

Steinmo, S.H., Michie, S., Fuller, C., Stanley, S., Stapleton, C. and Stone, S.P. (2015). Bridging the Gap Between Pragmatic Intervention Design and Theory: Using Behavioural Science Tools to Modify an Existing Quality Improvement Programme to Implement "Sepsis Six." *Implementation Science*, 11(1), pp.14–25.

Stephens, A., Pregelj, L., Smith, A. and Hine, D. (2021). *Adaptive Regulation for Digital Health: Enhancing Australia's Regulation System*. Queensland: MTP Connect.

Stoeva, P. (2020). International Norm Development and Change: Can International Law Play a Meaningful Role in Curbing the Lifestyle Disease Pandemic? *BMC International Health and Human Rights*, 20(1), pp.1–13.

Stokols, D. (1996). Translating Social Ecological Theory into Guidelines for Community Health Promotion. *American Journal of Health Promotion*, 10(4), pp.282–298.

Stokols, D. (2018). *Social Ecology in the Digital Age: Solving Complex Problems in a Globalised World*. Oxford: Academic Press.

Stolterman, E. (2008). The Nature of Design Practice and Implications for Interaction Design Research. *International Journal of Dsign*, 2(1), pp.55–65.

Stoyanov, S.R., Hides, L., Kavanagh, D.J. and Wilson, H. (2016). Development and Validation of the User Version of the Mobile Application Rating Scale (uMARS). *JMIR mHealth and uHealth*, 4(2), p.e72.

Stoyanov, S.R., Hides, L., Kavanagh, D.J., Zelenko, O., Tjondronegoro, D. and Mani, M. (2015). Mobile App Rating Scale: A New Tool for Assessing the Quality of Health Mobile Apps. *JMIR mHealth and uHealth*, 3(1), p.e27.

Stoytcheva, S. (2015). *Boundary Objects: A Field Guide: Boundary Objects*. [online] Boundary Objects: A Field Guide. Available at: https://scalar.usc.edu/works/boundary-objects-guide/boundary-objects [Accessed 16 Jul. 2021].

Stragier, J. (2017). *Physical Activity in the Digital Age: An Empirical Investigation into the Motivational Affordances of Online Fitness Communities*. PhD. Ghent University.

Strain, T., Brage, S., Sharp, S.J., Richards, J., Tainio, M., Ding, D., Benichou, J. and Kelly, P. (2020). Use of the Prevented Fraction for the Population to Determine Deaths Averted by Existing Prevalence of Physical Activity: A Descriptive Study. *The Lancet Global Health*, [online] 8(7), pp.e920–e930. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7303949/ [Accessed 15 Jul. 2021].

Strašunskas, D. (2006). *Domain Model-Centric Distributed Development: An Approach to Semantics-Based Change Impact Management*. PhD. Norwegian University of Science and Technology.

Strauss, A. (1978). A Social World Perspective. *Studies in Symbolic Interaction*, 1, pp.119–128.

Strauss, A.L. and Corbin, J.M. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. 2nd ed. Thousand Oaks: Sage Publications.

Stubbs, R. James, Duarte, C., O'Driscoll, R., Turicchi, J., Kwasnicka, D., Sniehotta, Falko F., Marques, Marta M., Horgan, G., Larsen, S., Palmeira, A., Santos, I., Teixeira, Pedro J.,

Halford, J. and Heitmann, B. (2021). The H2020 “NoHoW Project”: A Position Statement on Behavioural Approaches to Longer-Term Weight Management. *Obesity Facts*, 14(2), pp.246–258.

Subrahmanian, E., Monarch, I., Konda, S., Granger, H., Milliken, R., Westerberg, A. and Thendim group (2003). Boundary Objects and Prototypes at the Interfaces of Engineering Design. *Computer Supported Cooperative Work (CSCW)*, 12(2), pp.185–203.

Sucala, M. and Ezeanochie, N. (2019). Glimpse into the Future – How will the Field of Digital Health Evolve in the Next 5 Years? *UCL Institute of Healthcare Engineering*. [online] 8 Aug. Available at: https://www.ucl.ac.uk/healthcare-engineering/news/2019/aug/blog-glimpse-future-how-will-field-digital-health-evolve-next-5-years [Accessed 17 Jul. 2021].

Sucala, M., Cole-Lewis, H., Arigo, D., Oser, M., Goldstein, S., Hekler, E.B. and Diefenbach, M.A. (2021). Behaviour Science in the Evolving World of Digital Health: Considerations on Anticipated Opportunities and Challenges. *Translational Behavioural Medicine*, 11(2), pp.495–503.

Sucala, M., Ezeanochie, N.P., Cole-Lewis, H. and Turgiss, J. (2020). An Iterative, Interdisciplinary, Collaborative Framework for Developing and Evaluating Digital Behaviour Change Interventions. *Translational Behavioural Medicine*, 10(6), pp.1538–1548.

Suchman, L. (1994). Working Relations of Technology Production and Use. *Computer Supported Cooperative Work*, 2(1-2), pp.21–39.

Sullivan, A.N. and Lachman, M.E. (2017). Behaviour Change with Fitness Technology in Sedentary Adults: A Review of the Evidence for Increasing Physical Activity. *Frontiers in Public Health*, 4(289), pp.1–16.

Supporting the Challenges of Cross-Boundary Teamwork Through Design Science Research. (2018). PhD. University of Lausanne (Université de Lausanne).

Swain, J. (2018). A Hybrid Approach to Thematic Analysis in Qualitative Research: Using a Practical Example. *Sage Research Methods Cases*, [online] pp.1–28. Available at: https://methods.sagepub.com/case/hybrid-approach-thematic-analysis-qualitative-

research-a-practical-example [Accessed 15 Jul. 2021].

Swan, M. (2012). Health 2050: The Realisation of Personalised Medicine Through Crowdsourcing, the Quantified Self, and the Participatory Biocitizen. *Journal of Personalised Medicine*, 2(3), pp.93–118.

Swedberg, R. (2016). Before Theory Comes Theorising or Hhow to Make Social Science More Interesting. *The British Journal of Sociology*, 67(1), pp.5–22.

Swedberg, R. (2016). Can You Visualize Theory? On the Use of Visual Thinking in Theory Pictures, Theorising Diagrams, and Visual Sketches. *Sociological Theory*, 34(3), pp.250–275.

Swedberg, R. (2017). Theorising in Sociological Research: A New Perspective, a New Departure? *Annual Review of Sociology*, 43(1), pp.189–206.

Tabish, S.A. (2017). Lifestyle Diseases: Consequences, Characteristics, Causes and Control. *Journal of Cardiology & Current Research*, 9(3), pp.1–4.

Taj, F., Klein, M.C.A. and van Halteren, A. (2019). Digital Health Behaviour Change Technology: Bibliometric and Scoping Review of Two Decades of Research. *JMIR mHealth and uHealth*, 7(12), pp.1–21.

Tam, K. (2020). *Application of the Social Cognitive Theory to an Electronic Activity Monitor System-Based Physical Activity Intervention for Working Adults*. PhD. Hong Kong Baptist University.

Tang, J., Abraham, C., Stamp, E. and Greaves, C. (2015). How Can Weight-Loss App Designers' Best Engage and Support Users? A Qualitative Investigation. *British Journal of Health Psychology*, 20(1), pp.151–171.

Tavares, B.F., Pires, I.M., Marques, G., Garcia, N.M., Zdravevski, E., Lameski, P., Trajkovik, V. and Jevremovic, A. (2020). Mobile Applications for Training Plan Using Android Devices: A Systematic Review and a Taxonomy Proposal. *Information*, 11(7), p.343.

Taylor, N., Lawton, R. and Conner, M. (2013). Development and Initial Validation of the Determinants of Physical Activity Questionnaire. *International Journal of Behavioural Nutrition and Physical Activity*, 10(1), pp.74–84.

Taylor, T. (2018). Continuous Testing Mobile Devices. *Sauce Labs*. Available at: https://saucelabs.com/blog/continuous-testing-for-mobile-devices [Accessed 17 Jul. 2021].

Taylor, W.P. (1936). What is Ecology and What Good is it? *Ecology*, 17(3), pp.333–346.

Te Morenga, L., Pekepo, C., Corrigan, C., Matoe, L., Mules, R., Goodwin, D., Dymus, J., Tunks, M., Grey, J., Humphrey, G., Jull, A., Whittaker, R., Verbiest, M., Firestone, R. and Ni Mhurchu, C. (2018). Co-Designing an mHealth Tool in the New Zealand Māori Community with a "Kaupapa Māori" Approach. *AlterNative: An International Journal of Indigenous Peoples*, 14(1), pp.90–99.

Teixeira, P. (2015). A Primer on Self-Regulation and Health Behaviour Change. *Arch Exerc Health Dis*, 5(1-2), pp.326–337.

Tell, F., Berggren, C., Brusoni, S. and van de Ven, A. (2017). *Managing Knowledge Integration across Boundaries*. Oxford: Oxford University Press.

Tellioğlu, H. (2009). Keeping Artifacts Alive. In: *Proceedings of the International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing '09*. [online] pp.1–6. Available at: https://dl.acm.org/doi/10.1145/1731740.1731786 [Accessed 17 Jul. 2021].

Teyhen, D.S., Robbins, D. and Ryan, B.A. (2018). Promoting and Sustaining Positive Personal Health Behaviours – Putting the Person First. *Military Medicine*, 183(3), pp.213–219.

Thabrew, H., Fleming, T., Hetrick, S. and Merry, S. (2018). Co-Design of eHealth Interventions with Children and Young People. *Frontiers in Psychiatry*, 9, pp.1–6.

Tharchen, T., Garud, R. and Henn, R.L. (2020). Design as an interactive boundary object. *Journal of Organisation Design*, 9(1), pp.1–34.

Thurmond, V.A. (2001). The Point of Triangulation. *Journal of Nursing Scholarship*, 33(3), pp.253–258.

Timmermans, S. and Tavory, I. (2012). Theory Construction in Qualitative Research. *Sociological Theory*, 30(3), pp.167–186.

Tipton, C.M. (2014). The history of "Exercise Is Medicine" in ancient civilizations. *Advances in Physiology Education*, 38(2), pp.109–117.

Tong, H.L. and Laranjo, L. (2018). The Use of Social Features in Mobile Health Interventions to Promote Physical Activity: A Systematic Review. *NPJ Digital Medicine*, 1(1), p.43.

Tong, H.L., Coiera, E. and Laranjo, L. (2018). Using a Mobile Social Networking App to Promote Physical Activity: A Qualitative Study of Users' Perspectives. *Journal of Medical Internet Research*, 20(12), p.e11439.

Tong, H.L., Coiera, E., Tong, W., Wang, Y., Quiroz, J.C., Martin, P. and Laranjo, L. (2019). Efficacy of a Mobile Social Networking Intervention in Promoting Physical Activity: Quasi-Experimental Study. *JMIR mHealth and uHealth*, 7(3), p.e12181.

Torous, J., Wisniewski, H., Bird, B., Carpenter, E., David, G., Elejalde, E., Fulford, D., Guimond, S., Hays, R., Henson, P., Hoffman, L., Lim, C., Menon, M., Noel, V., Pearson, J., Peterson, R., Susheela, A., Troy, H., Vaidyam, A. and Weizenbaum, E. (2019). Creating a Digital Health Smartphone App and Digital Phenotyping Platform for Mental Health and Diverse Healthcare Needs: An Interdisciplinary and Collaborative Approach. *Journal of Technology in Behavioural Science*, 4(2), pp.73–85.

Townsend, N. and Foster, C. (2013). Developing and Applying a Socio-Ecological Model to the Promotion of Healthy Eating in the School. *Public Health Nutrition*, 16(6), pp.1101–1108.

Tozzi, C. (2017). Mobile Apps and Continuous Delivery. *Sauce Labs*. Available at: https://saucelabs.com/blog/mobile-apps-and-continuous-delivery [Accessed 17 Jul. 2021].

Tremblay, M.S., Aubert, S., Barnes, J.D., Saunders, T.J., Carson, V., Latimer-Cheung, A.E., Chastin, S.F.M., Altenburg, T.M. and Chinapaw, M.J.M. (2017). Sedentary Behaviour Research Network (SBRN) – Terminology Consensus Project Process and Outcome. *International Journal of Behavioural Nutrition and Physical Activity*, 14(1), pp.75–91.

Trompette, P. and Vinck, D. (2009). Revisiting the Notion of Boundary Object. *Revue d'Anthropologie des Connaissances*, [online] 3(1), pp.3–25. Available at: https://halshs.archives-ouvertes.fr/halshs-00483731 [Accessed 16 Jul. 2021].

Truelove, S., Vanderloo, L.M., Tucker, P., Di Sebastiano, K.M. and Faulkner, G. (2020). The Use of the Behaviour Change Wheel in the Development of ParticipACTION's Physical Activity App. *Preventive Medicine Reports*, 20, p.101224.

Truex, D., Holmström, J. and Keil, M. (2006). Theorising in Information Systems Research: A Reflexive Analysis of the Adaptation of Theory in Information Systems Research. *J. Assoc. Inf. Syst.*, 7(12), pp.797–821.

Tsang, E.W.K. and Williams, J.N. (2012). Generalization and Induction: Misconceptions, Clarifications, and a Classification of Induction. *MIS Quarterly*, 36(3), pp.729–748.

Tsoukas, H. (2009). A Dialogical Approach to the Creation of New Knowledge in Organisations. *Organisation Science*, 20(6), pp.941–957.

Tu, R., Hsieh, P. and Feng, W. (2019). Walking for Fun or for "Likes"? The Impacts of Different Gamification Orientations of Fitness Apps on Consumers' Physical Activities. *Sport Management Review*, 22(5), pp.682–693.

Tuckett, A. (2005). Part II: Rigour in Qualitative Research - Complexities and Solutions. *Nurse Researcher*, 13(1), pp.29–42.

Uddin, R., Lee, E.Y., Khan, S.R., Tremblay, M.S. and Khan, A. (2020). Clustering of Lifestyle Risk Factors for Noncommunicable Diseases in 304,779 Adolescents from 89 Countries: A Global Perspective. *Preventive Medicine*, 131, pp.1–8.

United Nations (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. [online] New York: United Nations. Available at: https://sdgs.un.org/2030agenda [Accessed 15 Jul. 2021].

Uppström, E. (2017). *Designing, Theorising, and Reflecting on Information Systems Artifacts and Value Co-Creation in e-Government*. PhD. Stockholm University.

Uusitalo, U. (2015). *Show me Your Brain! Stories of Interdisciplinary Knowledge Creation in Practice. Experiences and Observations from Aalto Design Factory, Finland*. PhD. Lappeenranta University of Technology.

Vaishnavi, V.K. and Kuechler, W. (2004). *Design Research in Information Systems*. [online] Design Science Research in Information Systems (DESRIST). Available at:

http://desrist.org/desrist/article.aspx [Accessed 15 Jul. 2021].

Vaishnavi, V.K. and Kuechler, W. (2008). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. Boca Raton, FL: Auerbach Publications.

Vaishnavi, V.K. and Kuechler, W. (2015). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. 2nd ed. Boca Raton, FL: CRC Press.

Vaishnavi, V.K., Kuechler, W. and Petter, S. (2017). *Design Science Research in Information Systems*. [online] Design Science Research in Information Systems (DESRIST). Available at: http://www.desrist.org/design-research-in-information-systems/ [Accessed 15 Jul. 2021].

Van Amstel, D., Heemskerk, M., Renes, R. and Hermsen, S. (2017). The Value of Agile Methods in Designing for Behavioural Change: A Case Study. *The Design Journal*, 20(S1), pp.S681–S690.

Van de Ven (2007). *Engaged Scholarship: A Guide for Organisational and Social Research*. Oxford: Oxford University Press.

Van der Merwe, A., Gerber, A. and Smuts, H. (2020). Guidelines for Conducting Design Science Research in Information Systems. In: *ICT Education*. [online] Available at: https://link.springer.com/chapter/10.1007%2F978-3-030-35629-3_11 [Accessed 15 Jul. 2021].

Van der Ploeg, H.P. and Hillsdon, M. (2017). Is Sedentary Behaviour Just Physical Inactivity by Another Name? *International Journal of Behavioural Nutrition and Physical Activity*, 14(1), pp.142–149.

Van Enst, W.I. (2018). *Science-Policy Interfaces for Enriched Environmental Decision-Making: A Research into the Strategies of Boundary Work, Illustrated by Case Studies in the Dutch Wadden Sea*. PhD. Utrecht University.

Van Gemert-Pijnen, J.E., Nijland, N., van Limburg, M., Ossebaard, H.C., Kelders, S.M., Eysenbach, G. and Seydel, E.R. (2011). A Holistic Framework to Improve the Uptake

and Impact of eHealth Technologies. *Journal of Medical Internet Research*, 13(4), pp.1–25.

Van Gemert-Pijnen, J.E., Nijland, N., van Limburg, M., Ossebaard, H.C., Kelders, S.M., Eysenbach, G. and Seydel, E.R. (2019). *The CeHRes Roadmap Toolkit*. [online] Universiteit Twente. Available at: https://www.utwente.nl/en/bms/ehealth/cehres-roadmap-toolkit/cehres-phases/ [Accessed 17 Jul. 2021].

Van Gemert-Pijnen, L., Kelders, S.M., Kip, H. and Sanderman, R. (2018). *eHealth Research, Theory and Development*. London: Routledge.

Van Haasteren, A., Vayena, E. and Powell, J. (2020). The Mobile Health App Trustworthiness Checklist: Usability Assessment. *JMIR mHealth and uHealth*, 8(7), p.e16844.

Van Velthoven, M.H., Smith, J., Wells, G. and Brindley, D. (2018). Digital Health App Development Standards: A Systematic Review Protocol. *BMJ Open*, 8(8), p.e022969.

Vandelanotte, C., Van Itallie, A., Brown, W., Mummery, W.K. and Duncan, M.J. (2020). Every Step Counts: Understanding the Success of Implementing The 10,000 Steps Project. *Studies in Health Technology and Informatics*, [online] 268, pp.15–30. Available at: https://pubmed.ncbi.nlm.nih.gov/32141876/ [Accessed 17 Jul. 2021].

Vaquero, R.C. (2016). *Design and Evaluation of a Mobile Fitness Application to Encourage People in Physical Activity*. Masters. Tampere University of Technology.

Vargo, D., Zhu, L., Benwell, B. and Yan, Z. (2020). Digital Technology Use During COVID-19 Pandemic: A Rapid Review. *Human Behaviour and Emerging Technologies*, 3(1), pp.13–24.

Vashist, R. (2012). *A Boundary Practice Perspective on the Roles and Practices of Business Analysts*. PhD. Swinburne University of Technology.

Vasileiou, K., Barnett, J., Thorpe, S. and Young, T. (2018). Characterising and Justifying Sample Size Sufficiency in Interview-Based Studies: Systematic Analysis of Qualitative Health Research Over a 15-Year Period. *BMC Medical Research Methodology*, 18(1).

Venable, J. (2006). A Framework for Design Science Research Activities. In: M. Khosrow-Pour, ed., *Emerging Trends and Challenges in Information Technology Management*.

Hershey: Idea Group Inc, pp.184–187.

Venable, J., Pries-Heje, J. and Baskerville, R. (2016). FEDS: A Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, 25(1), pp.77–89.

Venkatesh, V., Thong, J.Y.L. and Xu, X. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly*, 36(1), p.157.

Verbiest, M.E.A., Corrigan, C., Dalhousie, S., Firestone, R., Funaki, T., Goodwin, D., Grey, J., Henry, A., Humphrey, G., Jull, A., Vano, M., Pekepo, C., Morenga, L.T., Whittaker, R. and Mhurchu, C.N. (2018). Using Codesign to Develop a Culturally Tailored, Behaviour Change mHealth Intervention for Indigenous and Other Priority Communities: A Case Study in New Zealand. *Translational Behavioural Medicine*, 9(4), pp.720–736.

VicHealth (2019). *Physical Activity Strategy 2019-2023*. [online] Victoria: VicHealth. Available at: https://www.vichealth.vic.gov.au/media-and-resources/publications/physical-activity-strategy# [Accessed 16 Jul. 2021].

Vieira, E.A.O., da Silveira, A.C. and Martins, R.X. (2019). Heuristic Evaluation on Usability of Educational Games: A Systematic Review. *Informatics in Education*, 18(2), pp.427–442.

Villinger, K., Wahl, D.R., Boeing, H., Schupp, H.T. and Renner, B. (2019). The Effectiveness of App-Based Mobile Interventions on Nutrition Behaviours and Nutrition-Related Health Outcomes: A Systematic Review and Meta-Analysis. *Obesity Reviews*, 20(10), pp.1465–1484.

Vincent, K., Steynor, A., Waagsaether, K. and Cull, T. (2018). Communities of Practice: One Size Does Not Fit All. *Climate Services*, 11, pp.72–77.

Vom Brocke, J. and Maedche, A. (2019). The DSR Grid: Six Core Dimensions for Effectively Planning and Communicating Design Science Research Projects. *Electronic Markets*, 29(3), pp.379–385.

Vom Brocke, J., Hevner, A. and Maedche, A. (2020). Introduction to Design Science Research.

In: *Design Science Research Cases*. [online] pp.1–13. Available at: https://link.springer.com/chapter/10.1007%2F978-3-030-46781-4_1 [Accessed 16 Jul. 2021].

Vom Brocke, J., Winter, R., Hevner, A. and Maedche, A. (2020). Accumulation and Evolution of Design Knowledge in Design Science Research: A Journey Through Time and Space. *Journal of the Association for Information Systems*, 21(3), pp.520–544.

Von Hohenheim, P.T. (1533). *Von der Bergsuct und anderen Bergkrankheiten (On the Miner's Sickness and other Miners Diseases)*.

Vos, J.F.J., Boonstra, A., Kooistra, A., Seelen, M. and van Offenbeek, M. (2020). The Influence of Electronic Health Record Use on Collaboration Among Medical Specialties. *BMC Health Services Research*, 20(1).

Vos, S., Janssen, M., Goudsmit, J., Lauwerijssen, C. and Brombacher, A. (2016). From Problem to Solution: Developing a Personalised Smartphone Application for Recreational Runners following a Three-step Design Approach. *Procedia Engineering*, 147, pp.799–805.

Vygotsky, L.S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press.

Wahlstedt, L. (2014). *Dynamic Knowledge Integration: A Field Study of an Information Systems Development Project*. PhD. Linköping University.

Wall, S.D. (2017). *Finding Ways to Engage with a Healthy Tourism "Offer": Evaluating Potential Synergies Between Wellbeing, Public Health, and Tourism at a Local Destination*. PhD. Bournemouth University.

Wallace, C. (2020). *Boundary Spanning for Health: A Framework and Model to Improve Access to Health Services in High Income Countries*. PhD. Swinburne University of Technology.

Walls, J.G., Widmeyer, G.R. and El Sawy, O.A. (1992). Building an Information System Design Theory for Vigilant EIS. *Information Systems Research*, 3(1), pp.36–59.

Walsh, D.M.J., Moran, K., Cornelissen, V., Buys, R., Claes, J., Zampognaro, P., Melillo, F.,

Maglaveras, N., Chouvarda, I., Triantafyllidis, A., Filos, D. and Woods, C.B. (2019). The Development and Codesign of the PATHway Intervention: A Theory-Driven eHealth Platform for the Self-Management of Cardiovascular Disease. *Translational Behavioural Medicine*, 9(1), pp.76–98.

Walsh, J.C. and Groarke, J.M. (2019). Integrating Behavioural Science with Mobile (mHealth) Technology to Optimise Health Behaviour Change Interventions. *European Psychologist*, 24(1), pp.38–48.

Walsham, G. (2006). Doing Interpretive Research. *European Journal of Information Systems*, 15(3), pp.320–330.

Walton, J.S. (2008). Scanning Beyond the Horizon: Exploring the Ontological and Epistemological Basis for Scenario Planning. *Advances in Developing Human Resources*, 10(2), pp.147–165.

Wang, Y. (2019). *Designing Digital Health Interventions for Sedentary Behaviour Change*. PhD. University of Konstanz.

Wang, Y. and Wang, J. (2020). Modelling and Prediction of Global Noncommunicable Diseases. *BMC Public Health*, 20(1), pp.1–13.

Wang, Y., Fadhil, A., Lange, J. and Reiterer, H. (2019). Integrating Taxonomies into Theory-Based Digital Health Interventions for Behaviour Change: A Holistic Framework. *JMIR Research Protocols*, [online] 8(1), pp.1–11. Available at: https://arxiv.org/pdf/1810.08812.pdf [Accessed 17 Jul. 2021].

Wang, Y., Fadhil, A., Lange, J.P. and Reiterer, H. (2017). Towards a Holistic Approach to Designing Theory-Based Mobile Health Interventions. *Human Computer Interaction*, [online] pp.1–25. Available at: https://arxiv.org/abs/1712.02548 [Accessed 16 Jul. 2021].

Wartofsky, M.W. (1979). *Models: Representation and the Scientific Understanding*. Amsterdam: Springer Netherlands.

Wazlawick, R.S. (2014). *Object-Oriented Analysis and Design for Information Systems: Modeling with UML, OCL, and IFML*. Waltham: MK Publications.

Webb, T.L., Joseph, J., Yardley, L. and Michie, S. (2010). Using the Internet to Promote Health

Behaviour Change: A Systematic Review and Meta-Analysis of the Impact of Theoretical Basis, Use of Behaviour Change Techniques, and Mode of Delivery on Efficacy. *Journal of Medical Internet Research*, 12(1), pp.1–24.

Weber, R. (2004). The Rhetoric of Positivism versus Interpretivism: A Personal View. *MIS Quarterly*, 28(1), pp.iii–xii.

Weber, S. (2010). Design Science Research: Paradigm or Approach? In: *AMCIS 2010 Proceedings*. [online] pp.1–8. Available at: https://aisel.aisnet.org/amcis2010/214/ [Accessed 15 Jul. 2021].

Weick, K.E. (1989). Theory Construction as Disciplined Imagination. *The Academy of Management Review*, [online] 14(4), pp.516–531. Available at: https://www.jstor.org/stable/258556 [Accessed 15 Jul. 2021].

Weick, K.E. (1995). What Theory is Not, Theorising is. *Administrative Science Quarterly*, 40(3), pp.385–390.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. New York: Cambridge University Press.

Wenger, E. (2000). Communities of Practice and Social Learning Systems. *Organisation*, 7(2), pp.225–246.

Wenger, E. (2010). Communities of Practice and Social Learning Systems: The Career of a Concept. In: C. Blackmore, ed., *Social Learning Systems and Communities of Practice*. London: Springer, pp.179–198.

Wenger, E., McDermott, R. and Snyder, W. (2002). *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Boston, MA: Harvard Business School Press.

Wenger-Trayner, B., Wenger-Trayner, E., Cameron, J., Eryigit-Madzwamuse, S. and Hart, A. (2017). Boundaries and Boundary Objects: An Evaluation Framework for Mixed Methods Research. *Journal of Mixed Methods Research*, [online] pp.1–36. Available at: https://journals.sagepub.com/doi/abs/10.1177/1558689817732225 [Accessed 17 Jul. 2021].

Wenger-Trayner, E., Fenton-O'Creevy, M., Hutchinson, S., Kubiak, C. and Wenger-Trayner,

B. (2015). *Learning in Landscapes of Practice: Boundaries, Identity, and Knowledgeability in Practice-Based Learning*. Abingdon: Routledge.

West, R. (2017). Tobacco Smoking: Health Impact, Prevalence, Correlates and Interventions. *Psychology & Health*, 32(8), pp.1018–1036.

Westmaas, J., Gil-Rivas, V. and Silver, R.C. (2007). Designing and Implementing Interventions to Promote Health and Prevent Illness. In: H.S. Friedman and R.C. Silver, eds., *Foundations of Health Psychology*. Oxford University Press, pp.52–70.

Whitehead, M., Dahlgren, G. and Gilson, L. (2001). Developing the Policy Response to Inequities in Health: A Global Perspective. In: T. Evans, M. Whitehead, F. Diderichsen, A. Bhuiya and M. Wirth, eds., *Challenging Inequities in Health: From Ethics to Action*. New York: Oxford University Press, pp.309–324.

Whiting, L.S. (2008). Semi-Structured Interviews: Guidance for Novice Researchers. *Nursing Standard*, 22(23), pp.35–40.

Whittaker, R., Merry, S., Dorey, E. and Maddison, R. (2012). A Development and Evaluation Process for mHealth Interventions: Examples from New Zealand. *Journal of Health Communication*, 17(S1), pp.11–21.

Wiafe, I. (2012). *A Framework for Analysing, Designing and Evaluating Persuasive Technologies*. PhD. University of Reading.

Wickramasinghe, N. (2019). Essential Considerations for Successful Consumer Health Informatics Solutions. *Yearbook of Medical Informatics*, 28(1), pp.158–164.

Wiemeyer, J. (2019). Evaluation of Mobile Applications for Fitness Training and Physical Activity in Healthy Low-Trained People - A Modular Interdisciplinary Framework. *International Journal of Computer Science in Sport*, 18(3), pp.12–43.

Wight, D., Wimbush, E., Jepson, R. and Doi, L. (2015). Six Steps in Quality Intervention Development (6SQuID). *Journal of Epidemiology and Community Health*, 70(5), pp.520–525.

Wilhide III, C.C., Peeples, M.M. and Anthony Kouyaté, R.C. (2016). Evidence-Based mHealth Chronic Disease Mobile App Intervention Design: Development of a Framework. *JMIR*

*Research Protocols*, 5(1), p.e25.

Williams, P. (2012). *Collaboration in Public Policy and Practice: Perspectives on Boundary Spanners*. Bristol: The Policy Press.

Wilson, D.H. (1995). *An Approach to Implementing Multiple Inheritance in an Object-Oriented Programming Language*. Masters. Lehigh University.

Wilson, J.R. (2002). Responsible Authorship and Peer Review. *Science and Engineering Ethics*, 8(2), pp.155–174.

Wilson, K., Bell, C., Wilson, L. and Witteman, H. (2018). Agile Research to Complement Agile Development: A Proposal for an mHealth Research Lifecycle. *NPJ Digital Medicine*, 1(1), pp.1–6.

Wingood, G.M. and DiClemente, R.J. (2019). Accelerating the Evolution of Health Promotion Research: Broadening Boundaries and Improving Impact. *American Journal of Public Health*, 109(S2), pp.S116–S116.

Winkler, M.A.E., Huber, T.L. and Dibbern, J. (2014). The Software Prototype as Digital Boundary Object - A Revelatory Longitudinal Innovation Case. In: *International Conference on Information Systems (ICIS)*. [online] Available at: https://boris.unibe.ch/59153/ [Accessed 16 Jul. 2021].

Wohlrab, R., Pelliccione, P., Knauss, E. and Larsson, M. (2018). Boundary Objects in Agile Practices. In: *Proceedings of the 2018 International Conference on Software and System Process*. [online] pp.1–10. Available at: https://dl.acm.org/doi/10.1145/3202710.3203155 [Accessed 17 Jul. 2021].

Wong, C.C.K. and Kwok, R.C.W. (2016). The Effect of Gamified mHealth App on Exercise Motivation and Physical Activity. In: *PACIS 2016 Proceedings*. [online] Available at: http://aisel.aisnet.org/pacis2016/389 [Accessed 16 Jul. 2021].

Wood, P.H.N. (1986). Health and Disease and its Importance for Models Relevant to Health Research. In: B.W. Nizetic, H.G. Pauli and P.G. Svensson, eds., *Scientific Approaches to Health and Healthcare*. Copenhagen: World Health Organisation, pp.57–70.

World Health Organisation (2000). *Global Strategy for the Prevention and Control of*

*Noncommunicable Diseases: Report by the Director-General*. [online] Geneva: World Health Organisation. Available at: http://apps.who.int/gb/archive/pdf_files/EB105/ee42.pdf [Accessed 15 Jul. 2021].

World Health Organisation (2004). *WHO Global Strategy on Diet, Physical Activity and Health*. [online] Geneva: World Health Organisation. Available at: https://apps.who.int/iris/handle/10665/43035?search-result=true&query=2004+global+strategy+on+diet&scope=%2F&rpp=10&sort_by=score&order=desc [Accessed 16 Jul. 2021].

World Health Organisation (2008). *2008-2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/publications/i/item/9789241597418 [Accessed 15 Jul. 2021].

World Health Organisation (2009). *Milestones in Health Promotion: Statements from Global Conferences*. [online] Geneva: World Health Organisation. Available at: https://apps.who.int/iris/handle/10665/70578 [Accessed 15 Jul. 2021].

World Health Organisation (2010a). *Global Status Report on Noncommunicable Diseases 2010*. [online] Geneva: World Health Organisation. Available at: http://digicollection.org/hss/en/m/abstract/Js18629en/ [Accessed 15 Jul. 2021].

World Health Organisation (2010b). *Global Recommendations on Physical Activity for Health*. [online] World Health Organisation. Available at: https://www.who.int/publications/i/item/9789241599979 [Accessed 16 Jul. 2021].

World Health Organisation (2011). *mHealth: New Horizons for Health Through Mobile Technologies: Second Global Survey on eHealth*. [online] Geneva: World Health Organisation. Available at: https://apps.who.int/iris/handle/10665/44607 [Accessed 16 Jul. 2021].

World Health Organisation (2013). *Global Action Plan for the Prevention and Control of NCDs 2013-2020*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/publications/i/item/9789241506236 [Accessed 15 Jul. 2021].

World Health Organisation (2014). *Global Status Report on Noncommunicable Diseases 2014*.

[online] World Health Organisation. Available at: https://www.who.int/publications/i/item/9789241564854 [Accessed 15 Jul. 2021].

World Health Organisation (2016). *Report on the Status of Major Health Risk Factors for Noncommunicable Diseases: WHO African Region, 2015*. [online] World Health Organisation African Region. Available at: https://www.afro.who.int/publications/report-status-major-health-risk-factors-noncommunicable-diseases-who-african-region-0 [Accessed 15 Jul. 2021].

World Health Organisation (2017a). *Noncommunicable Diseases Progress Monitor 2017*. [online] World Health Organisation. Available at: https://www.who.int/publications/i/item/9789241513029 [Accessed 15 Jul. 2021].

World Health Organisation (2017b). *Montevideo Roadmap 2018-2030 on NCDs as a Sustainable Development Priority*. [online] World Health Organisation. Available at: https://reliefweb.int/report/world/montevideo-roadmap-2018-2030-ncds-sustainable-development-priority [Accessed 15 Jul. 2021].

World Health Organisation (2018a). *Global Action Plan on Physical Activity 2018-2030 - More Active People for a Healthier World*. [online] World Health Organisation. Available at: http://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf [Accessed 15 Jul. 2021].

World Health Organisation (2018b). *mHealth: Use of Appropriate Digital Technologies for Public Health: Report by the Director-General*. [online] World Health Organisation. Available at: https://apps.who.int/iris/handle/10665/274134 [Accessed 15 Jul. 2021].

World Health Organisation (2019). *WHO Guideline: Recommendations on Digital Interventions for Health System Strengthening*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/reproductivehealth/publications/digital-interventions-health-system-strengthening/en/ [Accessed 15 Jul. 2021].

World Health Organisation (2020a). *Noncommunicable Diseases Progress Monitor 2020*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/publications/i/item/ncd-progress-monitor-2020 [Accessed 15 Jul. 2021].

World Health Organisation (2020b). *The Top 10 Causes of Death*. [online] World Health Organisation. Available at: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death [Accessed 15 Jul. 2021].

World Health Organisation (2020c). *WHO Guidelines on Physical Activity and Sedentary Behaviour*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/publications/i/item/9789240015128 [Accessed 15 Jul. 2021].

World Health Organisation (2020d). *Responding to Noncommunicable Diseases During and Beyond the COVID-19 Pandemic: A Rapid Review*. [online] World Health Organisation. Available at: https://www.who.int/publications/i/item/WHO-2019-nCoV-Non-communicable_diseases-Evidence-2020.1 [Accessed 15 Jul. 2021].

World Health Organisation (2020e). *Physical Activity*. [online] World Health Organisation. Available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity [Accessed 15 Jul. 2021].

World Health Organisation (2020f). *Constitution of the World Health Organisation*. [online] Geneva: World Health Organisation. Available at: https://apps.who.int/gb/bd/pdf_files/BD_49th-en.pdf#page=6 [Accessed 15 Jul. 2021].

World Health Organisation (2020g). *Be He@lthy Be Mobile*. [online] Geneva: World Health Organisation. Available at: https://www.who.int/initiatives/behealthy [Accessed 17 Jul. 2021].

World Health Organisation (2021). *Noncommunicable Diseases*. [online] World Health Organisation. Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases [Accessed 15 Jul. 2021].

Worrall, A. (2014). *The Roles of Digital Libraries as Boundary Objects within and Across Social and Information Worlds*. PhD. Florida State University.

Wu, H. (2020). *An All-in-One mHealth Applications - #Beats - Your Health Mate*. Masters. Universitat de Barcelona.

Wunsch, K., Eckert, T., Fiedler, J., Cleven, L., Niermann, C., Reiterer, H., Renner, B. and Woll, A. (2020). Effects of a Collective Family-Based Mobile Health Intervention Called

"SMARTFAMILY" on Promoting Physical Activity and Healthy Eating: Protocol for a Randomised Controlled Trial. *JMIR Research Protocols*, 9(11), p.e20534.

Xu, W. and Zammit, K. (2020). Applying Thematic Analysis to Education: A Hybrid Approach to Interpreting Data in Practitioner Research. *International Journal of Qualitative Methods*, 19, pp.1–9.

Yang, C., Maher, J.P. and Conroy, D.E. (2015). Implementation of Behaviour Change Techniques in Mobile Applications for Physical Activity. *American Journal of Preventive Medicine*, 48(4), pp.452–455.

Yardley, L., Ainsworth, B., Arden-Close, E. and Muller, I. (2015a). The Person-Based Approach to Enhancing the Acceptability and Feasibility of Interventions. *Pilot and Feasibility Studies*, 1(37), pp.1–7.

Yardley, L., Morrison, L., Bradbury, K. and Muller, I. (2015b). The Person-Based Approach to Intervention Development: Application to Digital Health-Related Behaviour Change Interventions. *Journal of Medical Internet Research*, 17(1), pp.1–15.

Yardley, L., Spring, B.J., Riper, H., Morrison, L.G., Crane, D.H., Curtis, K., Merchant, G.C., Naughton, F. and Blandford, A. (2016). Understanding and Promoting Effective Engagement With Digital Behaviour Change Interventions. *American Journal of Preventive Medicine*, 51(5), pp.833–842.

Yein, N. (2021). *A Study on Developing an Interactive Stepping Exercise Tool to Improve Physical Balance of Elderly Population in India*. PhD. Indian Institute of Technology Guwahati.

Yen, H.Y. and Li, C. (2019). Determinants of Physical Activity: A Path Model Based on an Ecological Model of Active Living. *PLOS ONE*, 14(7), pp.1–13.

Yerrakalva, D., Yerrakalva, D., Hajna, S. and Griffin, S. (2019). Effects of Mobile App Interventions on Sedentary Time, Physical Activity and Fitness in Older Adults: Systematic Review and Meta-Analysis. *Journal of Medical Internet Research*, 21(11).

Young, M.D., Plotnikoff, R.C., Collins, C.E., Callister, R. and Morgan, P.J. (2014). Social Cognitive Theory and Physical Activity: A Systematic Review and Meta-Analysis.

*Obesity Reviews*, 15(12), pp.983–995.

Yu, N. and Huang, Y.T. (2020). Important Factors Affecting User Experience Design and Satisfaction of a Mobile Health App—A Case Study of Daily Yoga App. *International Journal of Environmental Research and Public Health*, 17(19), p.6967.

Zapata-Lamana, R., Lalanza, J.F., Losilla, J.M., Parrado, E. and Capdevila, L. (2020). mHealth technology for ecological momentary assessment in physical activity research: a systematic review. *PeerJ*, [online] 8, p.e8848. Available at: https://pubmed.ncbi.nlm.nih.gov/32257648/ [Accessed 17 Jul. 2021].

Zeiher, J., Manz, K., Kuntz, B., Perumal, N., Keil, T., Mensink, G.B.M. and Finger, J.D. (2020). Individual and Interpersonal Correlates of Cardiorespiratory Fitness in Adults – Findings from the German Health Interview and Examination Survey. *Scientific Reports*, 10(1), pp.445–459.

Zhang, C., Zhang, X. and Halstead-Nussloch, R. (2014). Assessment Metrics, Challenges, and Strategies for Mobile Health Apps. *Issues in Information Systems*, 15(II), pp.59–66.

Zhang, Y., Yin, Y., Liu, J., Yang, M., Liu, Z. and Ma, X. (2020). Impact of Combined Theory-Based Intervention on Psychological Effects and Physical Activity among Chinese Adolescents. *International Journal of Environmental Research and Public Health*, 17(9), pp.3026–3041.

Zhao, J., Freeman, B. and Li, M. (2016). Can Mobile Phone Apps Influence People's Health Behaviour Change? An Evidence Review. *Journal of Medical Internet Research*, 18(11).

Zhou, L., Bao, J., Setiawan, I.M.A., Saptono, A. and Parmanto, B. (2019). The mHealth App Usability Questionnaire (MAUQ): Development and Validation Study. *JMIR mHealth and uHealth*, 7(4), p.e11500.

Zimmerman, J., Forlizzi, J. and Evenson, S. (2007). Research Through Design as a Method for Interaction Design Research in HCI. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '07*. [online] Available at: https://dl.acm.org/citation.cfm?id=1240704.

Zoom (2021). *Zoom*. [online] Zoom. Available at: https://zoom.us/ [Accessed 17 Jul. 2021].

# Appendices

# Appendix A (Chapter 3): A Critical Discussion on the Debated Concept of Health

## 3.3 Health Promotion: Addressing the Global Health Status on Noncommunicable Diseases and their Associated Modifiable Health Risk Behaviours

### Excerpt from Start of Chapter 3, Section 3.3

Addressing the global health status on noncommunicable diseases (NCDs) requires a thorough understanding of the concept and definition of *health*, and the *health promotion* landscape in general. According to the World Health Organisation (WHO, 2014b, p.1), health is characterised by an implied intrinsic relationship between the human body and self, and is defined as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"*. The feasibility and pragmatic realisation of this definition has, however, received a fair dose of criticism over the last several decades (Callanhan, 1973; Bice, 1976; Garner, 1979; Ware and Young, 1979; Wood, 1986; Blaxter, 1990; Saracci, 1997; Larson, 1999; Jadad and O'Grady, 2008; Blaxter, 2010; Huber, et al., 2011; Awofeso, 2012; Huber, 2014; Huber, et al., 2016). Appendix A provides a detailed critical discussion and review on the debated concept of health; excluded from this main body discussion due to its extensive nature, yet is referenced and appendicised to demonstrate the researcher's understanding of the concept and definition of health.

### Full Critical Discussion on the Debated Concept of Health

*Health*, as a concept, has been around for millennia (dating back to Egyptian Medicine, 3000 BCE; Chinese Medicine, 2200 BCE; Hippocrates and Western Medicine, 400 BCE; Vinel and Pialoux, 2005; Ancient History Encyclopedia, 2017) and in light of the current status on global health, remains a substantially researched and evolving phenomenon in today's age (WHO, 2017). In the wake of World War II, the World Health Organisation (WHO) signed (1946) and adopted (1948) a revised global outlook on *health* by characterising an implied intrinsic relationship between the human body and self, defining it as "*A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" (WHO, 2014b,

p.1). The feasibility and pragmatic realisation of this definition, however, has received its fair dose of criticism over the last several decades (Callanhan, 1973; Bice, 1976; Garner, 1979; Ware and Young, 1979; Wood, 1986; Blaxter, 1990; Saracci, 1997; Larson, 1999; Jadad and O'Grady, 2008; Blaxter, 2010; Huber, et al., 2011; Awofeso, 2012; Huber, 2014; Huber, et al., 2016). From a philosophical standpoint, the concept of health is not only central in the field of medicine, but also in health psychology, behavioural psychology, behavioural medicine, medical psychology, medical sociology, psychosomatic medicine and the social sciences, amongst others (Bircher and Kuruvilla, 2014; Morrison and Bennett, 2016). The lack of consensus arises from the complex and somewhat elusive nature of health, demonstrated through its multidimensional array of social, medical, psychological, behavioural, economic, political, epidemiological and spiritual components (Larson, 1999; Amzat and Razum, 2014; Huber, et al., 2016).

A principal critique of the WHO's definition relates to its specification for a 'complete' state of health, which offers an aspirational goal, yet is disputed as neither realistically obtainable nor measurable (Callanhan, 1973; Saracci, 1997; Jadad and O'Grady, 2008; Awofeso, 2012) and "would leave most of us unhealthy most of the time" (Smith, 2008, p.1). Additional criticisms refer to the WHO's omission for spiritual health (Larson, 1996), an impractical operationalisation of a 'complete state' of health (Huber, et al., 2011; Amzat and Razum, 2014; Huber, 2014) and its vaguely implied synonymity with the concept of wellbeing (Tulloch, 2005; Huber, et al., 2011). Further critiques highlight the definition's implied declaration for individuals with physical, psychological, behavioural and emotional disorders and disabilities, as well as chronic (that is, noncommunicable) diseases, as definitively ill (Saracci, 1997; Smith, Jadad and O'Grady, 2009; Huber, et al., 2016). Moreover, the WHO's definition suggests that individuals living with such diagnoses are less, if not at all, capable of leading healthy lifestyles and experiencing a positive state of wellbeing whilst autonomously coping with life's ever-changing emotional, social, physical and psychological demands and obstacles (Tulloch, 2005; Huber, et al., 2011; Huber, 2014). This requirement is simply unrealistic since some degree of noncommunicable (or communicable) disease and infirmity is "perfectly compatible" with – and hence does not necessarily diminish – one's state of social, emotional, mental, physical and spiritual health and wellbeing (Callanhan, 1973, p.87; Huber, 2014).

In light of the heavy criticism of the WHO's official definition, and in response to the changing global health and NCD circumstances, several scholars have proposed varying alternative definitions (Parsons, 1972; Saracci, 1997; Larson, 1999; Bircher, 2005; Blaxter, 2010; Huber,

et al., 2011; Shilton, et al., 2011; Huber, 2014); none of which are without reasonable strengths and limitations (Amzat and Razum, 2014). A more recent operational definition proposed by Huber, et al. (2011, p.2) describes the concept of health *"as the ability to adapt and self-manage in the face of social, physical and emotional challenges"*. That is, in facing various health-related challenges (such as NCDs) in addition to other daily-faced routine upsets (for example, missing an indoor cycling session because of traffic). Huber, et al.'s (2011) term 'adapt' offers a dynamic alternate perspective to the WHO's recommended, yet impractical and unobtainable utopic, 'complete state' of health; a perpetual 'state' of being that cannot realistically be maintained (Smith, Jadad and O'Grady, 2009). This proposed revision for adaptive and self-managerial capability is supported by other researchers, such as Shilton, et al. (2011) and Jambroes, et al. (2016), since it considers the diverse array of ongoing developments and contemporary shifts concerning the health and wellbeing of society and its individuals.

When initially defined, morbidity mainly featured communicable (infectious) diseases, whereas in today's age, NCDs are more prevalent, yet the acquiring of a NCD should not imply an individual is unable to adapt and manage their condition (or conditions) accordingly, and does not necessarily deter a continued healthy existence (Amzat and Razum, 2014; Huber, et al., 2016). Nevertheless, Huber, et al.'s (2011) adaptive and self-managerial perspective is not without criticism. Blaxter (2010) for instance, disputes that a life-long dependence on medication and/or assistive treatment is not necessarily suffice for a satisfactorily healthy or worthwhile existence. Additionally, an adaptive and self-managerial perspective on one's relative experience of health and wellbeing is arguably subjective, based on one's own self-reflexive assessment, experiences, circumstances and experiential knowledge (Amzat and Razum, 2014). Notably, acknowledgements are made by Huber, et al (2016) that not necessarily all individuals wish to accept self-responsibility for their own modifiable (risk) behaviours and hence, prefer to not assume sufficient self-accountability for their lifestyle choices and decisions that ultimately end up affecting their long-term personal health and wellbeing.

While these criticisms of Huber, et al.'s (2011) definition are reasonably valid, infusing the 'adaption' and 'self-management' of one's own health and wellbeing provides consideration for the various dynamic fluctuations related to individuals' states of health across biographical, historical, contextual, medical and personal circumstances (Huber, et al., 2016). In addition to these considerations, Huber, et al.'s (2011) viewpoint of health also acknowledges the various external social, economic, environmental and political factors, all of which further affect one's intrinsic ability to adapt and self-manage their own health and wellbeing within a given context

or set of circumstances (Huber, et al., 2016). Moreover, this broadened perspective hinges on a worldview directed at the empowerment of individuals, through which ways of adapting and self-managing one's own health and wellbeing can be learnt and adopted within differing contexts (Huber, et al., 2011; 2016). The WHO's definition, on the contrary, implies a passivity that lacks support and encouragement for the modes of action required in obtaining mental, social and physical health. Huber, et al.'s (2011) view also takes into account six subjective dimensions related to wellbeing, namely one's: bodily functions, mental functions and perception, daily functioning, social and societal participation, quality of life, as well as a spiritual or existential component (Huber, 2014; Huber, et al., 2016).

With these points in mind, it becomes apparent that Huber, et al.'s (2011) outlook on the concept of health complements the changing patterns in NCDs and morbidity (Jambroes, et al., 2016) and the global movements made over the last four decades (O'Donnell, 1986; WHO, 1986; 2016) towards a more proactive, promotive approach to the health and wellbeing of society and its individuals. In other words, the adaptive, self-managerial and preventative (that is, proactive) approach to health is in accordance with the field of *Health Promotion*; a theoretically- and empirically-based health domain that has been increasingly advocated for since the late 1970s and early 1980s (US Department of Health, 1979; O'Donnell, 1986; WHO, 1986; 2016).

Despite these reasonable and justified criticisms shining a spotlight on the impracticality of aiming for and achieving a utopic 'complete state' of health, the WHO's definition for health currently remains unchanged, primarily owing to its measurable and reportable simplicity. In other words, the definition is easier to measure and report on in comparison to the other, broader and more modern alternative proposed definitions. Given the WHO definition's overarching cementation in the universal discussions on and reportings of health and health behavioural policy interventions over the last several decades, the WHO's (2014b) definition is adopted as the grounding concept upon which the health domain is further researched throughout this thesis. Although, in light of the considerations for the 'adaptable' and 'self-managerial' nature of health, and given this thesis' orientation towards preventative and proactive approaches to health (in line with the field of Health Promotion) and the modification of individuals' (NCD-related) health risk behaviours, the WHO's definition will be coupled with Huber, et al.'s (2011; Huber, 2014) definition throughout this thesis. This coupling of definitions is primarily by reason of Huber, et al.'s (2011; Huber, 2014) broader, more dynamic perspective taken on the concept of health; one that considers the support, encouragement and empowerment of

individuals in developing their own knowledge and skills, in enabling them to self-adapt and self-manage their own health and wellbeing in the face of lifestyle and routine challenges. This dual perspective adopted on the concept of health caters for individuals who exhibit a willingness to empower themselves in proactively self-managing their own health and wellbeing through modifying lifestyle risk behaviours (such as increased physical activity and healthy eating), and further considers individuals that wish to accept additional professional aid and support in changing their lifestyle decisions and behaviours.

In further outlining the contextual landscape of this thesis, and in particular reference to the use of the terms *'health'* and *'wellbeing'*, distinctions should be highlighted between what can seemingly – yet mistakenly – be conceived as interchangeable or synonymous concepts. On the one hand, as stipulated in the WHO's definition (2014b, p.1), the concept of health refers to one's 'state' of physical, social and mental being; 'state' implying a static condition or status at a specific point in time (Jonas, 2005; Foster and Keller, 2008). Wellbeing, on the other hand, describes the lifelong active 'process' of becoming aware of one's lifestyle choices and making decisions towards leading a more balanced, fulfilling and optimal existence (Hettler, 1980; Seligman, 2011). This is a 'dynamic', rather than a static, 'process' that implies the continuous search, exploration and discovery of appropriate tools for enhancing one's health, happiness and general life satisfaction (Seligman, 2002; Diener, Scollon and Lucas, 2003; Charlemagne-Badal, et al., 2015); a 'process' and way of living that has no end (Jonas, 2005).

Wellbeing considers the continuous growth and development of one's whole self and is inherently a value judgement based on an individual's subjective attitudinal perspectives and sense of emotional psychological satisfaction across their own holistic (that is, their 'whole') being (Foster and Keller, 2008; Seligman, 2011; Dodge, et al., 2012). This holism encompasses one's happiness and emotional psychological satisfaction for their quality of life (Foster and Keller, 2008) across emotional, spiritual, intellectual, psychological, physical, occupational and environmental dimensions (Seligman, 2011), thus making the concept of wellbeing comparatively more holistic than the concept of health (Charlemagne-Badal, et al., 2015). Wellbeing can be visualised as a see-saw calibration which places wellbeing at the centre – depicting an individual's inevitable need for equilibrium or homeostasis – in between the two fluctuating states of an individual's (psychological, emotional, social, spiritual and physical) resources and challenges (Dodge, et al., 2012).

Wellbeing, similarly to health, is not the complete absence of disease or negative affect, but rather entails a goal whereby one is capable of functionally processing, feeling, experiencing and managing (health and daily routine) challenges with one's resources; so as to continuously return oneself to a sufficiently satisfying state of equilibrium or homeostasis (Dodge, et al., 2012). The absence of consistently variable interactions, on the contrary, can result in stagnation, which is also detrimental to an individual's overall health and wellbeing (Charlemagne-Badal, et al., 2015). The foci of study in health, according to the WHO (2014) covers the mental, social and physical dimensions, whereas the foci of study in wellbeing (also referred to as wellness) is orientated towards an individual's self-conceived feelings of fulfilment, satisfaction and happiness across their multidimensional holistic being (Seligman, 2011; Charlemagne-Badal, et al., 2015). An individual can be physically healthy, for instance, but may be experiencing overall negative emotional psychological affect if their other dimensions of wellbeing are deficient or unsatisfactory. Health, in effect, becomes a resource for the ongoing journey for obtaining improved wellbeing and optimal life satisfaction (Jonas, 2005). Examples of health as a resource can include: physical activity; healthy diet; positive social relationships; positive emotions and balanced moods; life satisfaction; engaging activities and work; mental stability; and a healthy sense of worthiness, self-esteem, self-efficacy, resilience and autonomy (Seligman, 2011; Dodge, et al., 2012).

The concept of wellbeing is thus predominantly researched and interpreted through a psychological lens, in which the sense of self – namely, one's self-concept, autonomy, self-acceptance, personal growth, life purpose, self-accomplishment – and sense of happiness, interpersonal connectedness and internal feelings of fulfilment, are central (Foster and Keller, 2008; Seligman, 2011). These variables contributing to and describing the wellbeing of an individual are largely subjective and individualistically self-measured (Jonas, 2005). Thus, relative to health, wellbeing describes a broader, more holistically multifaceted, vague, intangible and complex concept (Foster and Keller, 2008; Dodge, et al., 2012). This multidimensional and subjective nature makes defining and measuring wellbeing even more difficult than the concept of health (Seligman, 2011; Dodge, et al., 2012; Charlemagne-Badal, et al., 2015). As a result, literature holds a range of proposed definitions of wellbeing, yet there remains a lack of consensus and resolution for an official definition (Diener, Scollon and Lucas, 2003; Seligman, 2011; Dodge, et al., 2012; Charlemagne-Badal, et al., 2015).

With regard to the scope of this research thesis, no further research or investigation will be conducted into the ill-defined, subjective, complex, elusive and intrinsically multifaceted nature

of wellbeing. Furthermore, this thesis is not based in the discipline of Psychology, but is rather inherently based in the Information Systems discipline, and thus does not aim to primarily contribute to research in the wellness domain. Distinguishing between the concepts of health and wellbeing has, nevertheless, been necessary in delineating and understanding the landscape of this research project. In short, health is a noun, whereas wellbeing is a derivative adverb of the noun well. Health is a state, whereas wellbeing is a dynamic process whereby one continuously seeks to manage and improve their own social, emotional, psychological, physical, spiritual, occupational, economic and personal development as a means to obtaining positive affect and overall life satisfaction. The concepts of health and wellbeing are undeniably intertwined, demonstrated by their frequent mistaken use as interchangeable synonyms across lay and academic spheres. Essentially, one can think of health as a resource or stepping-stone to achieving optimal wellbeing.

The modification of health risk behaviours (such as increased physical activity and healthy eating) act as resources or tools for improved wellbeing and enhanced life satisfaction. These resourceful lifestyle modifications or tools are integral in the movement towards NCD prevention and health promotion (WHO, 1986; Whitehead, Dahlgren and Gilson, 2001; O'Donnell, 2009; Charlemagne-Badal, et al., 2015); as demonstrated in the WHO's global health targets and strategic health behavioural policy interventions (WHO, 2010a; 2013; 2014; 2018b; 2020c). Huber, et al.'s (2011) definition of health enriches the WHO's traditional view by considering the dynamic, adaptive and self-managerial nature in which people can modify their health-related lifestyle risk behaviours as stepping stones to increased happiness and holistic wellbeing.

In the fight against the global NCD pandemic, supporting, empowering and enabling individuals to take proactive and preventative action in modifying and changing their own health- and lifestyle-related behaviours is fundamental in the field of *Health Promotion* (O'Donnell, 2009; Huber, 2014; Charlemagne-Badal, et al., 2015; Huber, et al., 2016; WHO, 2018b). The field of *Health Promotion* is core to the development of interventions intended to encourage, support and empower individuals in modifying their health- and lifestyle-related risk behaviours (such as increased physical activity and healthy eating) in order to increase their overall health and wellbeing, as well as prevent and reduce the chances of developing a NCD (or comorbid cluster of NCDs).

# Appendix B (Chapter 3): Reference List for Determinants and Correlates for Physical Activity Behaviour

## 3.5.2 Health Promotion Behaviour Change Interventions for Physical Activity: Determinants and Correlates of Physical Activity at the Intra-Interpersonal Socioecological Levels


Aleksovska, K., Puggina, A., Giraldi, L., Buck, C., Burns, C., Cardon, G., Carlin, A., Chantal, S., Ciarapica, D., Colotto, M., Condello, G., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J. and Izzicupo, P. (2019). Biological Determinants of Physical Activity Across the Life Course: A "Determinants of Diet and Physical Activity" (DEDIPAC) Umbrella Systematic Literature Review. *Sports Medicine Open*, 5(1), pp.1–18.

Atkin, A.J., van Sluijs, E.M.F., Dollman, J., Taylor, W.C. and Stanley, R.M. (2016). Identifying Correlates and Determinants of Physical Activity in Youth: How Can We Advance the Field? *Preventive Medicine*, 87, pp.167–169.

Bauman, A.E., Reis, R.S., Sallis, J.F., Wells, J.C., Loos, R.J. and Martin, B.W. (2012). Correlates of Physical Activity: Why Are Some People Physically Active and Others Not? *The Lancet*, 380(9838), pp.258–271.

Biddle, S.J.H., Mutrie, N., Gorely, T. and Faulkner, G. (2021). *Psychology of Physical Activity Determinants, Well-Being and Interventions*. 4th ed. New York: Routledge.

Brug, J., van der Ploeg, H.P., Loyen, A., Ahrens, W., Allais, O., Andersen, L.F., Cardon, G., Capranica, L., Chastin, S., De Bourdeaudhuij, I., De Craemer, M., Donnelly, A., Ekelund, U., Finglas, P., Flechtner-Mors, M., Hebestreit, A., Kubiak, T., Lanza, M., Lien, N. and MacDonncha, C. (2017). Determinants of Diet and Physical Activity (DEDIPAC): A Summary of Findings. *The International Journal of Behavioural Nutrition and Physical Activity*, 14, pp.1–24.

Choi, J., Lee, M., Lee, J., Kang, D. and Choi, J.-Y. (2017). Correlates Associated with Participation in Physical Activity Among Adults: A Systematic Review of Reviews and Update. *BMC Public Health*, 17(1), pp.356–369.

Condello, G., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Simon, C., Ciarapica, D., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P., Jaeschke, L. and Kanning, M. (2017). Behavioural Determinants of Physical Activity Across the Life Course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) Umbrella Systematic Literature Review. *International Journal of Behavioural Nutrition and Physical Activity*, 14(1).

Cortis, C., Puggina, A., Pesce, C., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Simon, C., Ciarapica, D., Condello, G., Coppinger, T., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P. and Jaeschke, L. (2017). Psychological Determinants of Physical Activity Across the Life Course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) Umbrella Systematic Literature Review. *PLOS ONE*, 12(8), p.e0182709.

Craggs, C., Corder, K., van Sluijs, E.M.F. and Griffin, S.J. (2011). Determinants of Change in Physical Activity in Children and Adolescents. *American Journal of Preventive Medicine*, 40(6), pp.645–658.

De Ridder, D., Kroese, F., Evers, C., Adriaanse, M. and Gillebaart, M. (2017). Healthy Diet: Health Impact, Prevalence, Correlates, and Interventions. *Psychology & Health*, 32(8), pp.907–941.

Dishman, R.K., Sallis, J.F. and Orenstein, D.R. (1985). The Determinants of Physical Activity and Exercise. *Public Health Rep*, 100(2), pp.158–171.

Egger, G. and Dixon, J. (2014). Beyond Obesity and Lifestyle: A Review of 21st Century Chronic Disease Determinants. *BioMed Research International*, 2014, pp.1–12.

Rhodes, R.E., Janssen, I., Bredin, S.S.D., Warburton, D.E.R. and Bauman, A. (2017). Physical Activity: Health Impact, Prevalence, Correlates and Interventions. *Psychology & Health*, 32(8), pp.942–975.

Sherwood, N.E. and Jeffery, R.W. (2000). The Behavioural Determinants of Exericse: Implications for Physical Activity Interventions. *Annual Review of Nutrition*, 20(1), pp.21–44.

Stanley, R.M., Ridley, K., Olds, T.S. and Dollman, J. (2014). Increasing Specificity of Correlate

Research: Exploring Correlates of Children's Lunchtime and After-School Physical Activity. *PLOS ONE*, 9(5), p.e96460.

Yen, H.Y. and Li, C. (2019). Determinants of Physical Activity: A Path Model Based on an Ecological Model of Active Living. *PLOS ONE*, 14(7), pp.1–13.

Zeiher, J., Manz, K., Kuntz, B., Perumal, N., Keil, T., Mensink, G.B.M. and Finger, J.D. (2020). Individual and Interpersonal Correlates of Cardiorespiratory Fitness in Adults – Findings from the German Health Interview and Examination Survey. *Scientific Reports*, 10(1), pp.445–459.

# Appendix C.1 (Chapter 4): Fields and Subfields of Biomedical Informatics and Health Informatics

## 4.2 The Digital Health Landscape – Consumer Health Informatics and mHealth Technology: Fields and Subfields of Biomedical Informatics and Health Informatics

| Research Fields and Sub-Fields in Biomedical and Health Informatics | | |
|---|---|---|
| **Sub-Field (Sub-Discipline)** | **Description** | **References** |
| **Biomedical Informatics (BMI)**<br><br>**(traditionally called Medical Informatics)** | *Biomedical Informatics (BMI)* , traditionally referred to as Medical Informatics (MI) (1980's), describes a multi-(and inter-) disciplinary field of study that focuses on the development, study and application of theory, techniques, methodologies, processes and methods for the effective use (collection, storage, analysis, retrieval, management and sharing) of biomedical data, information and knowledge for scientific enquiry, problem solving, and decision making. BMI is broad in scope, spanning from biological molecular, genomic and organ studies to medical and clinical research and practice; from individual to public population health; and is concerned with informatics across all types of healthcare, medical, clinical, allied and specialised research and practice. Essentially driven by efforts to improve human health, BMI considers the human and social context (that people are the ultimate users of biomedical information) and thus largely draws upon social, psychological, cognitive and behavioural sciences to inform the design, development, evaluation and maintenance of health-related technological solutions and policies, as well as the progressive evolution of economic, social, ethical, educational, health, organisational, governmental and global systems. | • Van Bemmel (1984)<br>• Greenes and Shortlife (1990)<br>• Bernstam, Smith and Johnson (2010)<br>• Kulikowski, et al. (2012)<br>• Nelson and Staggers (2016) |
| **Health Informatics (HI)**<br><br>**(also called Healthcare Informatics)** | *Health Informatics (HI)* is the scientific study and application of concepts, theories and practices concerning the acquisition, retrieval, usage, dissemination and storage of healthcare information in a way that fosters better collaborative links between information, technology, communications and healthcare service provision. HI is a multidisciplinary field including information sciences, computer sciences, management sciences, social sciences, behavioural sciences, and more. Is it the interdisciplinary study of the design, development, adoption, integration, application and management of information technologies and digital devices for optimising the use of health resources, information and methods in advancing healthcare practices, standards, service delivery, infrastructures and electronic health (eHealth). HI also involves the study, implementation and adoption of health information exchange standards including Health Level 7 (HL7), as well as standardised, multilingual vocabulary medical terminologies such as Systematised Nomenclature of Medicine (SNOWMED) and clinical terms (CT) such as SNOWMED-CT. HI is an overarching field of study and body of knowledge, including the sub-fields (sub-disciplines): public health informatics | • Imhoff, et al. (2001)<br>• Hovenga (2010)<br>• Coiera (2015)<br>• Nelson and Staggers (2016) |

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| | (PHI), clinical informatics (CI), bioinformatics (BI), consumer health informatics (CHI), pharmaceutical informatics, nursing informatics, imaging informatics, dental informatics, and pathological informatics, amongst others. | |
| **Public Health Informatics (PHI)** | *Public Health Informatics (PHI)* is a sub-discipline of study within HI. It studies the systematic application of information, computer science and technology in the area of public health research, practice and learning. The main applications of PHI include (1) epidemiological disease and injury risk prevention, and (2) health and wellness promotion efforts. PHI is concerned with the use (design, development, deployment, refinement, maintenance and advancement) of information systems technology for data collection, analysis and actions around the conceptualisation, surveillance, prevention, preparedness, reporting and promotion of health on a large population scale. PHI is considered most useful and effective when used in collaboration with governmental and regional or national regulatory structures. | • Magnuson and Fu (2014)<br>• Baker, et al. (2016)<br>• Aziz (2017) |
| **Clinical Informatics (CI)** | *Clinical Informatics (CI)*, a sub-discipline of HI, refers to the study and application of information and communication technology for the purpose of patient healthcare delivery. It is concerned with the collection, storage, use, dissemination, and sharing of patient healthcare information by clinicians across various health professional groups (such as physicians, dentists, pathologists, pharmacists, nurses or any other healthcare professional). Information systems are also used to: support clinical best practices and decision making (through summarisation, data visualisation, evidence provision and decision support systems); improve the flow, coordination and use of information and resources for optimising patients' (clinicians') and patients' workflows; and for maximising patient safety, engagement and care quality. CI also connects to and incorporates other disciplines such as nursing informatics, dental informatics and pathology informatics, provides order entry systems and supports clinical documentation and administration. | • Kulikowski, et al. (2012)<br>• Degoulet and Fieschi (2012)<br>• Shortliffe, Detmer and Munger (2016) |
| **Bioinformatics (BI)** | *Bioinformatics (BI)* is a sub-discipline of HI that focuses on research, development and application of informatics in (macro)molecular, cellular, protein, and particularly genomic (DNA, gene expression) studies. BI conceptualises biology in terms of molecules (in the sense of physical chemistry) and applying informatics techniques (derived from mathematics, computer science, information systems and statistics) to understand and organise the information associated with molecules, proteins and genes on a large scale. It is important to note that BI (a sub-discipline of biomedical informatics) is distinct from both BMI (the broad, overarching domain or field of medical informatics study). | • Luscombe, Greenbaum, Gertein (2001)<br>• Maoji and Kulikowski (2003)<br>• Hovenga (2010)<br>• Coiera (2015) |
| **Consumer Health Informatics (CHI)** | *Consumer Health Informatics (CHI)* is a rapidly evolving sub-discipline of BMI and HI that studies the design, development, implementation, maintenance and delivery of computer, telecommunication and digital technologies, applications and interfaces that support consumers in obtaining and analysing information, and making decisions, regarding their own health and wellbeing. CHI stands at the intersection of other HI disciplines such as public health informatics, health education, nursing informatics, communication science, information systems/sciences and health promotion. CHI analyses consumers' health information needs and preferences, and studies and implements methods for making health information and behavioural change interventions accessible and effective for consumers. CHI is a discipline concerned with any electronic tool, technology application or digital device that is primarily designed to interact directly with consumers (anyone who seeks or uses healthcare information for personal | • Ferguson (1995)<br>• Eysenbach, et al. (2000)<br>• Gustafson, et al. (2002)<br>• Bakker (2005)<br>• Lewis, Chang and Friedman (2005) |

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| | reasons), and may be used in coordination with, but is not dependent on a healthcare professional. CHI studies the use of technology platforms (and digital devices) and informatics as a means to provide consumers' with personalised and tailored health information, and decision-making and emotional support; with the intention of informing, educating, motivating and empowering individuals to better self-manage their own health, patient healthcare and holistic wellbeing. It studies the use of informatics from multiple consumer and/or patient perspectives, which aids the modelling and integration of consumers' needs and preferences into the design, development and delivery of consumer-based technologies and software applications that can provide personalised and individualised (health promotive) interventions and health information, and tailored assistance or recommendations in helping consumers modify their health behaviours and better manage their health, wellbeing and personal healthcare. Some of the common CHI tools (that is technology and digital devices used in the discipline of CHI) include: personal health records (PHRs), telehealth, mobile health (mHealth), games for health, Health 2.0, remote monitoring and videoconferencing equipment, wearable devices, sensor technology, and smartphone/tablet applications. | • Khan, et al. (2007)<br>• Keselman, et al. (2008)<br>• Alamantariotou, (2010)<br>• Gibbons, et al. (2011)<br>• Shaikh, et al. (2011)<br>• Houston, et al. (2012)<br>• Laxman, Krishnan and Dhillon (2015)<br>• Demiris (2016)<br>• Sheikh, et al. (2017)<br>• Faiola and Holden (2017) |

# Appendix C.2 (Chapter 4): Digital Health Technologies

## 4.2 The Digital Health Landscape – Consumer Health Informatics and mHealth Technology: Digital Health Technologies

| Digital Health Technologies | | |
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| **Digital Health Technology** | **Description** | **References** |
| **Digital Health Technology** | *Digital Health Technology* refers to the convergence of health, technology and society/individuals. Some of the tools and platforms in digital health technology include smartphones/tablets and wearable wireless devices; mobile and desktop applications; implantable microchips and devices; hardware sensors and software sensing technologies; microprocessors and integrated circuits; the internet; social networking and social media; mobile and body area networks; health information technology (HIT); genomics and personal genetic information. Digital health technologies include tools and platforms that are employed with the fields and subfields of mHealth; eHealth; wireless health; Health 2.0 and mHealth 2.0; HIT; big data; health data; ePatients; quantified self and self-tracking; cloud computing; wearable computing; gamification; telehealth and telemedicine; precision medicine and personalised medicine; and connected health. Other technologies that are increasingly being incorporated into digital health are 3D printing, microchips, augmented reality, smart health, machine learning and artificial intelligence. | • Eysenbach (2000)<br>• Laxman, Krishnan and Dhillon (2015)<br>• Lucivero and Prainsack (2015)<br>• Faiola and Holden (2017)<br>• Wickramasinghe (2019) |
| **Health Information Technology (HIT)**<br><br>**(also referred to as Healthcare Systems)** | *Health Information Technology (HIT)*, also referred to as *Healthcare Systems*, is an area of Information Technology (IT) that involves the design, development, implementation and maintenance of information and communication systems and infrastructures in healthcare. HITs are utilised within healthcare organisations to support the capturing, analysing, storing, retrieving and sharing of health information, and to support the management of resources, processes and practice workflows. HITs support the management and exchange of health information between healthcare providers, payers (private or insurance), consumers (or patients), and quality monitoring agencies. HITs also provide platforms for administrative efforts and (real-time) communicative interactions between various stakeholders, institutions and infrastructures. HITs are expected to reduce errors, lower costs, improve patient satisfaction and improve the overall effectiveness, efficiency and quality of patient healthcare. | • Davis and LaCour (2014)<br>• Adibi (2015)<br>• Sheikh, et al. (2017) |
| **eHealth (Electronic Health)** | The core of varying *Electronic Health (eHealth)* definitions emphasise the use of technology as a "tool" that enables the collection, storage, analysis, use, management, transfer and sharing of health data, information, resources and healthcare services. eHealth "tools" include any electronic technology, information systems, telecommunication devices, digital technology, the internet and electronic processes; all of which offer a "mode" for expanding, assisting, supporting, empowering, enabling, improving and enhancing human health-related activities, rather than substituting them. eHealth tools can be used for clinical, | • Eysenbach (2001)<br>• Oh, et al. (2005, p.9)<br>• Adibi (2015)<br>• Boogerd, et al. (2015) |

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| | patient and medical purposes, although eHealth is not solely about the provision of healthcare from health professionals and practitioners, but the use of consumer handheld technologies (such as smartphones/tablets) on a daily basis that enables the self-monitoring, self-management and self-care of one's own health and wellbeing. eHealth technologies provide a platform for interactions, communications and collaborations between various stakeholders in health, and also involves health via social media platforms. Eysenbach's (2001) (most cited, but outdated) definition describes eHealth as an emerging field of MI (BMI) that not only refers to technological developments or the delivery of health services and information through the internet and related technologies, but in a broader sense, describes a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology. Some of the main eHealth technologies includes patient health records (PHRs), electronic medical records (EMRs), electronic health records (EHRs), telehealth and telemedicine, and mobile health (mHealth) technologies. | • WHO (2016)<br>• Shaw, et al. (2017) |
| **Personal Health Record (PHR)** | A *Personal Health Record (PHR)* is an internet-based or electronic application through which patients can access, coordinate, manage, track and share their personal health information – relating to symptoms, medications, diagnoses, test results, pharmaceutics, self-help tools and insurance – in a private, secure and confidential environment. It is a consumer- or patient-centric system that can be used to track and support an individuals' health activities and status over time. All information in the PHR is managed by the consumer/patient themselves, who has control over with whom and when to grant access to shared personal health data and information. A PHR is therefore not limited to a single organisation, healthcare provider or insurance group, but rather follows a person over their entire (health-related) life experience. PHRs are also expected to conform to national interoperability standards which allows for interactive data exchange between healthcare providers, insurance companies, patient portals and the patient. | • The Markle Foundation (2003)<br>• NATH (2008)<br>• Demiris (2012)<br>• Abaidoo and Larweh (2014)<br>• Demiris (2016) |
| **Electronic Medical Record (EMR)** | *Electronic Medical Records (EMRs)* are computerised software and applications that enable the (legal and confidential) collection, storage and retrieval of health and medical data within hospital and ambulatory environments. EMRs support the creation and management of patients' electronic medical records and detailed medical information collected across inpatient (e.g. hospital) and outpatient (doctor's practice) environments, and are used by healthcare professionals and practitioners (not by patients or consumers) in documenting, recording, analysing, monitoring and managing healthcare service delivery with a particular healthcare organisation (such as a hospital). An EMR contains a patient's health history, doctors' or nurses' notes, and laboratory, pathology or radiology results. They are composed of clinical data repositories, clinical decision supports systems, controlled medical vocabulary, order entry, pharmacy and clinical documentations. EMRs are differentiated from PHRs in that they can only be accessed by doctors/nurses/healthcare professionals at the organisation (hospital/practice) and cannot be accessed by consumers/patients. | • The Markle Foundation (2003)<br>• Garets and Davis (2006)<br>• Davis and LaCour (2014) |
| **Electronic Health Record (EHR)** | An *Electronic Health Record (EHR)* is a network connection of multiple EMRs that provides a platform for the (legal and confidential) sharing of patients' medical data and health information amongst various stakeholders (including patients/consumers, healthcare providers, employers, insurance companies, and the government). EMRs are the source of health and clinical data for EHRs. EHRs are thus reliant on the development, implementation and integration of EMRs within various healthcare provider settings. EMRs, however, cannot reach their full potential if EHR interoperability structures are absent or | • Garets and Davis (2006)<br>• Deloitte (2015)<br>• WHO (2016) |

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| | malfunctioning. An EHR therefore refers to a set of electronic records that clinicians control to co-ordinate their team work within and between healthcare teams. The patient's information thus follows them through the various modalities of healthcare engaged by the individual, and can span multiple healthcare services and healthcare organisations/providers across multiple communities, regions, states/provinces or even across an entire country. | |
| **Telehealth** | *Telehealth* involves the consistent and timely recording, tracking, monitoring and managing of a health condition, such as vital signs monitoring. A telehealth tool exchanges health-related information between a patient and healthcare provider to identify trends or changes in a patient's condition remotely, helping to avoid hospital admission, supporting early discharge and improving post-discharge self-care. Telehealth technologies help educate, train and support people to self-care. | • Deloitte (2015) |
| **Telemedicine** | *Telemedicine* refers to the use of telecommunication and electronic information technologies to provide clinical healthcare (medical and specialist) services and health education at a geographical distance. It permits the transfer and exchange of medical, imaging and health informatics data from one site to another, between patients and clinical, medical or health specialist professionals. Telemedicine technologies facilitate medical and clinical consultations, including patient assessments, diagnoses and treatments, continuing professional education, ongoing care, health promotion and healthcare management. Telehealth and telemedicine tools help to improve healthcare services, promote healthy lifestyles and education where patients or clients are geographically separated, and thus provides significant assistance in rural healthcare delivery, inmate correction facilities, schools, industrial health services, disaster relief services and other mobile health facilities. | • Abaidoo and Larweh (2014)<br>• Davis and LaCour (2014)<br>• Deloitte (2015) |
| **mHealth (Mobile Health)** | *Mobile Health (mHealth)* is a sub-domain of eHealth and Digital Health Technology that uses mobile devices and assisted mobile communication technologies (including mobile phones, smartphones and tablets), patient monitoring devices, personal digital assistants, and other wireless, wearable and sensor devices for medical, public and consumer health purposes. mHealth technologies facilitate the collection, recording, tracking, storing and sharing of health data and information, and support health communications and collaborations between various interested parties. mHealth technologies can be used as tools for illness (or noncommunicable disease) prevention, diagnosis and treatment, medication / pharmaceutical drug adherence, health and wellness promotion, health education in general, and (ongoing, distance consult, outpatient or post-consult) patient care.<br><br>mHealth technologies allow for the accessing and sharing of health information, enable healthcare service delivery, support clinical decision making, and provide real-time monitoring and (intervention, treatment or medication) adherence support. They can be used in collaboration with or without (and hence are not always dependent on) healthcare professionals. mHealth utilises a mobile phone's core voice and messaging services (such as voice calls and SMSes), and more complex functionalities and applications (including general packet radio service (GPRS)), third and fourth generation mobile telecommunications (3G and 4G systems), global positioning systems (GPS), other wireless technologies (such as Bluetooth, Wi-Fi, WiMax, GSM technology. Notably, although the mHealth arena is quite broad, the proliferation of smartphone applications (apps), as a mHealth tool, has significantly transformed personalised and individualised healthcare. | • Istepanian, Laxminarayan and Pattichis (2006)<br>• WHO (2011)<br>• Adibi (2015)<br>• WHO (2016)<br>• Istepanian and Woodward (2016)<br>• Cameron, Ramaprasad and Syn (2017)<br>• Shaikh, et al. (2017) |

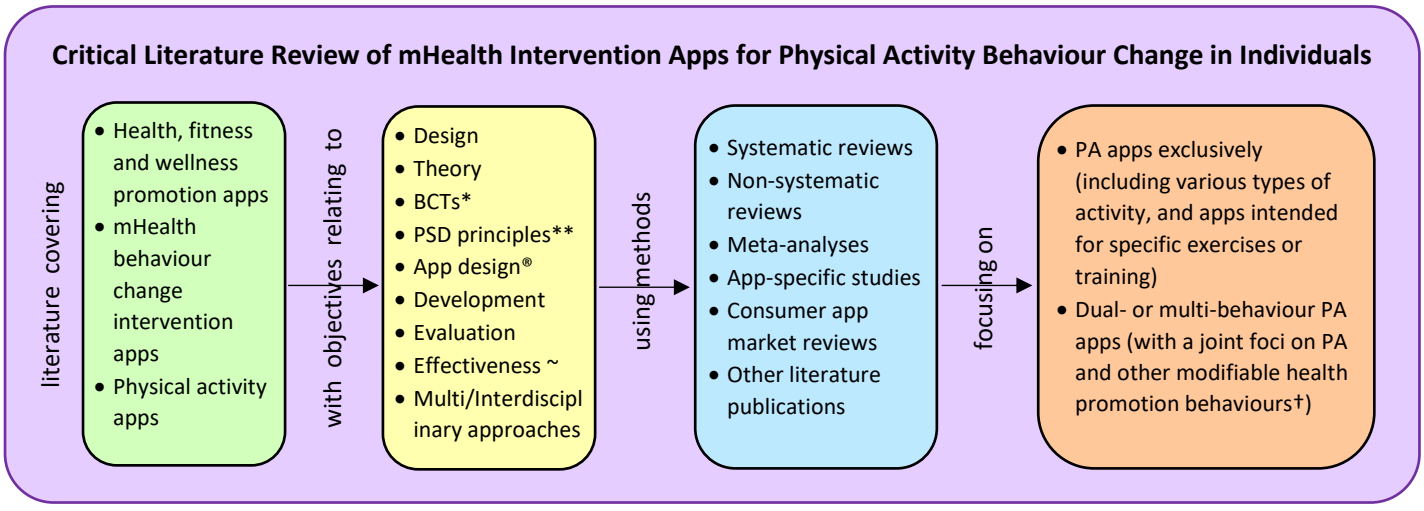
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| **Health and Wellness (Lifestyle Promotion) Applications (Apps)** | *Health and Wellness (Lifestyle Promotion) Applications (Apps)* constitute a sub-domain of mHealth, and have been rapidly revolutionising the consumer mobile (smartphone and tablet) app markets. mHealth smartphone and tablet applications (apps) can be described as software that runs on a mobile platform (meaning that it runs on the handheld commercial off-the-shelf computing platform itself, with or without wireless internet connectivity) or a web-based software platform that is tailored to a mobile platform but is executed on a server. Health and wellness apps have become popular tools for delivering health behaviour change interventions, can be linked to a variety of sensor and wearable technologies, connected to social media platforms, contribute to big data and the quantified self, and can operate as stand-alone, personal consumer products. The most popular health and wellness apps include: fitness and sporting activity tracking, nutrition and dietary intake tracking, weight loss coaching, sleep cycle analysis, stress reduction, relaxation, meditation, smoking cessation, psychiatric and behavioural modification assistance, chronic disease care management (such as diabetes and asthma), menstrual period tracking, and pregnancy and postnatal support. | • McGrath and Scanaill (2014)<br>• Research2<br>• Guidance (2014)<br>• Deloitte (2015)<br>• FDA (2015)<br>• Markets and Markets (2015)<br>• Millington (2016) |
| **Games for Health (Gamification)** | *Games for Health* and *Gamification* refer to the use of game design elements in non-game contexts. Gamification is becoming an increasingly popular tool for health promotion and behaviour change interventions – in accordance with the consumer- and patient-centric approach to healthcare. Gamification utilises techniques such as goal setting, feedback provision of performance, reinforcement and reward, competition, comparisons and social networking connectivity to stimulate motivation, self-efficacy, autonomy, empowerment and other socio- and cognitive-behavioural mechanisms to promote health behaviour changes in consumers and patients. Gamification is often utilised in conjunction with other platforms such as mHealth technologies, sensors and wearables, smartphone and tablet (health and wellness) apps, and social media. | • Edwards, et al. (2016)<br>• Johnson, et al. (2016)<br>• Nacke and Deterding (2017) |
| **Sensors and Wearables** | *Sensors and Wearables* are devices that can be worn to continuously and closely monitor an individual's activities, without interrupting or limiting the user's motions. Wearables use biosensors as analytic devices for tracking, recording and converting biological responses into electronic signals that can then be transferred to and shared with other platforms, such as smartphone applications and websites. Bio-sensing (biofeedback sensing) technology is able to monitor changes in a person's physiology (such as blood pressure, heart-pulse rate, galvanic skin responses (that is, electro-dermal activity – sweating and respiration)), and track human motion kinematics (using accelerometers, gyroscopes and magnetometers) in real-time. Some wearable devices include smart watches, glasses, clothing, and head-mounted technologies. Sensor and wearable technology is usually linked via Bluetooth or Wi-Fi with other platforms for the purpose of transferring and sharing the gathered data. | • Deloitte (2015)<br>• Haghi, Thurow and Stoll (2017) |
| **The Quantified Self** | *The Quantified Self* is a movement of individuals (as consumers) who are interested in using sensor and wearable devices and other computing and ubiquitous digital technologies to continuously track on a daily basis a variety of data about themselves in order to better understand their own health and wellbeing. This data usually includes dietary tracking, physical activities and fitness performance, sleep patterns, mood fluctuations or stability, time-management, stress monitoring, lifestyle behavioural habits and other key health or physiological metrics. The quantified self is a movement that demonstrates the essence of self-empowered consumers (and even diagnosed patients) who proactively seek ways of tracking, monitoring, managing and improving their own health and wellbeing. | • Swan (2012)<br>• McGrath and Scanaill (2014) |

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| **Health 2.0, mHealth 2.0 and Social Media** | *Health 2.0* and *mHealth 2.0* refer to the use of a specific set of Web 2.0 tools (such as podcasts, blogs, tagging, search, twitter, videos, online communities, and more) by actors in healthcare. Health 1.0 and mHealth 1.0 was about 'the technology itself', Health 2.0 and mHealth 2.0 emphasise the linkages and collaborations between various actors (including doctors, patients, health professionals and service providers, scientists, consumers and others) and Web 2.0 platforms (such as open source software, user-generated content, the internet of things, social networks and social media, cloud platforms, and more). The focus of Health 2.0 and mHealth 2.0 is orientated towards personalised, tailored and individualised consumer- and patient-centric healthcare, and consumer empowerment (to self-manage one's own health and wellbeing) that encourages and supports collaboration, and promotes health and wellbeing. Health 2.0 and mHealth 2.0 adopt a user-centred approach to technology design, and often links to other health (and eHealth) technologies including gamification, health and wellness apps, personal health records, sensors and wearables, the quantified self , eHealth systems, telehealth, telemedicine, and more.<br><br>*Social Media* platforms are already infiltrating society, largely affecting how people communicate, engage and interact with one another. Social media has broken down barriers, bridged people across vast geographical populations and significantly influenced the health, wellness, fitness and nutrition industry in a number of ways. One of the main ways social media has impacted the health arena is through online communities, photo and story-telling application services; which are predominantly driven by consumer- or patient-generated information. Some platforms are more medical or clinical orientated – for patients to communicate, share stories and support each other in terms of diagnoses, treatments, recovery and self-care. Other platforms are more personal lifestyle-orientated, where individuals tend to track, record, communicate and share their daily habits, photos and stories with each other. | • Hughes, Joshi and Wareham (2008)<br>• Van de Belt, et al. (2010)<br>• Swan (2012)<br>• Bates, et al. (2017)<br>• Mesko, et al. (2017) |
| **Big Data** | *Big Data* describes the voluminous amounts of unstructured and semi-structured data companies, governments, institutions, and individuals generate every single day using various information system and digital technologies. Sensor technologies are large generators and contributors to big data. Big sensor data can leverage cloud infrastructures to store, process and visualise data. Big data links data and information from various technologies (such as EMRs, EHRs, sensors and wearables, mobile devices and smartphones, social media, demographics) as a means to perform large-scale data mining analytics and data visualisation, pick up data trends and patterns, enhance machine learning and artificial intelligence. | • McGrath and Scanaill (2014)<br>• Bates, et al. (2017) |

# Appendix D (Chapter 4): Design Related Challenges in mHealth Behaviour Change Intervention Consumer Apps: A Critical Review

## 4.4.2 Design Related Challenges in mHealth Behaviour Change Intervention Consumer Apps: A Critical Review

The design related challenges discussed in this subsection are informed by various literature, systematic reviews, meta-analyses, meta-regressions, empirical study findings, and the researcher's own thorough critical literature review of such published works. The discussion in this subsection covers the four themes in an interrelated and interwoven manner; given the complex nature and interdependencies between the four challenges, they cannot be discussed distinctly or disjointedly. For purposes of length, this critical review (covering the four challenge themes) is included here in Appendix D, while the main themes and points of interest derived from this critical review are provided in the thesis's main body discussion in Subsection 4.4.2. Some critical review findings also inform the thesis's main body discussion in Subsection 4.4.3. Figure 4.3 outlines the key terms and area of foci used for conducting the critical literature review, which employed a hermeneutic literary search approach advocated for in information systems studies (Boell and Cecez-Kecmanovic, 2010; 2014).




** BCTs (Behaviour Change Techniques)*
*** PSD principles (Persuasive System Design principles)*
*® App design (including user interface design, user experience design, usability, aesthetics, engagement, gamification)*
*~ Effectiveness (including studies relating to efficacy, feasibility, adherence, usage, engagement and persuasiveness)*
*† Other modifiable health promotion behaviours include sedentary behaviour, diet and nutrition, weight loss/maintenance/gain, stress management, and sleep.*

*Figure 4.3: Critical Literature Review of mHealth Intervention Apps for Physical Activity Behaviour Change in Individuals (at the Dual Intra-Interpersonal Socioecological Levels) [Source: Researcher's own construction]*

# Critical Review* of Design Related Challenges (Excluded from Main Body of Thesis Discussion)

***Note:** The critical review in this appendix was conducted in early 2018 (and reviewed for editing in 2021). The critical review provided in the main body of Chapter 4, Subsection 4.4.2 was updated to include knowledge contributions and references spanning later 2018 to 2021, whereas the critical review in this appendix excludes these more recent citations.*

## 4.4.2.1 Critical Review: Introduction and Approach

The critical review discusses the study findings from a broad range of literature, extracted through several credible and reliable databases and academic publishers. Databases included Elsevier Scopus, Elsevier ScienceDirect, Clarivate Analytics (formerly Thomson Reuters) Web of Science, BMC, NCBI PubMed and PMC, ACM Digital Library, IEEE Xplore, SpringerNature SpringerLink, SAGE, Taylor&Francis Online, John Wiley & Sons Wiley Online Library). Academic journals included JMIR mHealth and uHealth, JMIR Human Factors, JMIR Public Health, American Journal of Preventative Medicine, British Medical Journal, BMC Public Health, Annals of Behavioural Medicine, Psychology & Health, Applied Psychology, Communications of the Association for Information Systems, European Journal of Information Systems). Other published papers and proceedings from influential and leading international conferences (for example, Persuasive Technology Conference, UCL's Centre for Behaviour Change Conference); search engines (for example Google Scholar); university thesis portal databases; and other credible sources (for example, ResearchGate) are also used.

A hermeneutic literature review approach is applied in searching for and discovering publications relevant to the design challenges faced with regard to mHealth (physical activity) behaviour change intervention apps (Boell and Cezec-Kecmanovic, 2011; 2014). As to date, studies investigating the design challenges pertaining to and the effectiveness of mHealth physical activity behaviour change intervention apps have been applied across a range of application contexts and empirical settings. Some have focused on apps to promote physical activity in health adults (Jee, 2017), others are conducted on specific demographic or target groups. For example, the elderly (King, et al., 2016; Paul, et al., 2017), children and adolescents (Schoeppe, et al., 2017; Watterson, et al., 2017), patients with certain chronic diseases or health issues (Barlett, 2015; Dahlke, et al., 2015; Bartlett, Webb and Hawley, 2017), and people of particular ethnic and national decent (Verbiest, et al., 2018). Considering the limited literature availability on physical activity apps in isolation, publications utilising a variety of study design

methods covering sedentary behaviour, weight loss/management and nutritional/dietary intake jointly with physical activity apps will be included in this critical review. These methods include systematic and non-systematic reviews, meta-analyses, randomised controlled trials, app-specific reviews, usability and user experience testing, questionnaires, surveys, interviews, cross-sectional, experimental and longitudinal studies. The publications inclusion are at the researcher's discretion – depending on the literary and knowledge value offered in relation to this research problem, and design related challenges.

The critical review discussion on the design challenges of mHealth (physical activity) behaviour change intervention apps is divided into four subsections. These subsections are in accordance with the research methods used by the various authors (Figure 4.3):

- Subsection 4.5.2.2: Systematic reviews, non-systematic reviews and meta-analyses
- Subsection 4.5.2.3: App-specific studies
- Subsection 4.5.2.4: Consumer app market reviews
- Subsection 4.5.2.5: Other literature publications

#### 4.4.2.2 Systematic Reviews, Non-Systematic Reviews and Meta-Analyses on the Design and Effectiveness of mHealth (Physical Activity) Behaviour Change Intervention Apps

This subsection discussion provides a critical overview of systematic literature reviews, non-systematic reviews and meta-analyses existing in the knowledge base (refer to Figure 4.3's first three bullet points under the "using methods" block). These reviews include (in descending chronological order): Jee (2017); Covolo, et al. (2017); Coughlin, et al. (2016); Zhao, Freeman and Li (2016); Mateo, et al. (2015); Payne, et al. (2015a); and Muntaner, Vidal-Conti and Palou (2015). The thesis main body discussion includes updated reviews dated 2018 to 2021.

***Jee, et al. (2017)***

A review conducted by *Jee (2017)* on 10 articles between years 2014 and 2017 concluded the publication availability on the feasibility, applicability and accuracy of physical activity apps as generally limited, with adequately applied study designs. The review findings revealed mixed results on the effectiveness of physical activity apps, and although studies consistently reported the motivational potential for apps to increase physical activity, user adherence and app usage rates tended to drop significantly after three months (Jee, 2017). A three-month

adherence period has been reported as an insufficient time duration for ensuring sustainable behavioural changes and positive physical activity habit formation (Recio-Rodríguez, et al., 2014; Gardner, 2015; Stawarz, Cox and Blandford, 2015). Jee's (2017) review findings found a noticeable number of publications emphasising the importance of incorporating behaviour change techniques (BCTs) (such as self-monitoring and goal-setting) in effectively promoting physical activity, and the need for apps to exhibit motivational, persuasive and attractive design features in creating for positive user experiences and long-term app user engagement.

***Covolo, et al. (2017)***

In a systematic review on the scientific evidence for the efficacy of mHealth lifestyle apps for promoting healthier lifestyles, *Covolo, et al. (2017)* summarised and examined the study findings of 40 randomised controlled trials (RCTs). Twenty-three of the 40 RCTs primarily targeted physical activity, eight of which were solely intended for physical activity, while four RCTs were aimed at physical activity and healthy eating, ten were aimed at increasing physical activity, improving healthy eating and weight management, and one RCT aimed at increasing physical activity and improving weight management. Of the 23 studies, four considered daily step counts, eight the frequency of physical activity, and nine the level and/or intensity of physical activity performance. In terms of positive effects, Covolo, et al. (2017) reported 30% of the 23 studies as demonstrating statistically significant differences between the intervention and control groups' outcome measures. However, 48% of the RCTs reviewed did not show a significant increase in physical activity in the intervention groups when followed up, and the rest of the RCTs provided mixed results (Covolo, et al., 2017).

Of the RCTs reviewed in Covolo, et al. (2017), studies using indirect and self-reported physical activity measures (for example, self-reported minutes and frequency of activity, and self-reported questionnaires) generally revealed negative results, compared to those utilising direct and objective physical activity measures (for example, smartphone device built-in sensors, accelerometers, pedometers and GPS technologies). A valuable finding of Covolo, et al.'s (2017) RCT-based systematic review revealed stand-alone physical activity apps as comparatively more effective than those utilising multi-tool interventions (which, for instance, utilise an app in conjunction with email communications, web programs, voice notes and phone calls). A study by Morrison, et al. (2014), however, found *POWeR Tracker* and *POWeR* (a multi-platform smartphone app and website intervention, respectively) as more effective than the isolated use of the *POWeR Tracker* app alone, explaining that the online intervention

supplemented the provision of relevant health information content and motivated increased user engagement with the intervention overall. On the contrary, Gasser, et al.'s (2006) study, which sought to compare the efficacy of a persuasive coaching smartphone app to a web-based app for tracking physical activity and diet over a four-week trial period, found more regular usage patterns with the smartphone app intervention group than the web-based intervention group.

***Coughlin, et al. (2016)***

To investigate the general acceptability and efficacy of smartphone mHealth intervention apps promoting physical activity, *Coughlin, et al. (2016)* conducted a review on 15 studies, including six qualitative research studies, eight RCTs and one nonrandomised study with pre-post design. The results of Coughlin, et al.'s (2016) review indicated smartphone apps as efficacious in promoting physical activity behaviour change, although the results from the RCTs demonstrated notably modest increases in physical activity and modest intervention effects (in terms of increased step-count and decreased body mass index). The results of the qualitative studies revealed participants of various ages and genders to respond favourably to mHealth physical activity behaviour change intervention apps that allow for tracking (for example, step counts), track progress towards physical activity goal achievement, and are user-friendly and flexible for use with several types of physical activity.

***Zhao, Freeman and Li (2016)***

A thematic literature review conducted by *Zhao, Freeman and Li (2016)* aimed to examine the effectiveness of health behaviour change apps in a broader range of interventions. Based on a review of 23 studies published between 2010 and 2015, four studies implemented and described mHealth app interventions for improved physical activity, weight management and healthy eating. The review results revealed significant changes through a reported increases in step-count (Rabbi, et al., 2015) and reductions in weight, fat loss, and body mass indices (Carter, et al., 2013; Laing, et al., 2014). Similarly to Coughlin, et al.'s (2016) and Jee's (2017) discussions, Zhao, Freeman and Li (2016) reiterate the importance in utilising psychology-based behaviour change theories, BCTs and well-designed app features and interfaces, in developing effective physical activity apps. Furthermore, in highlighting the limited availability of scientific evidence, Zhao, Freeman and Li (2016) emphasise the need for further rigorous research into the design, effectiveness and acceptability of health behaviour change apps. They also underscore the need for better multi-disciplinary team collaborations between researchers,

app developers and health behavioural scientists to enhance the design, development and evaluation of evidence-based health promoting behaviour change apps.

***Mateo, et al. (2015)***

*Mateo, et al. (2015)* conducted a systematic review and three meta-analyses on 12 articles, published between 2010 and August 2015, assessing the effectiveness of mHealth apps through physical activity outcomes (that is, increased exercise) and anthropometric health measures (including body mass index (BMI), weight and waist circumference). The first meta-analysis on the use of mHealth intervention apps for weight loss (including nine clinical trials) revealed significant decreases in weight, with a pooled estimates of net change in weight being -1.04 kg (95% confidence interval (CI) -1.75 to -0.34). The second meta-analysis on the efficacy of mHealth intervention apps targeting BMI reduction (including eight clinical trials) showed a significant net difference in BMI between app intervention groups and control groups, with a pooled estimates of net change in BMI being -0.43 $kg/m^2$ (95% CI -0.74 to -0.13). The third meta-analysis aimed to determine the effectiveness of mHealth intervention apps for physical activity (including seven clinical trials), with pooled results indicating a non-significant difference in physical activity between mHealth intervention app user groups and control groups (standardised mean difference of 0.40).

The results of Mateo, et al.'s (2015) meta-analyses on the effectiveness of mHealth physical activity behaviour change intervention apps, however, counter the findings and conclusions drawn by other systematic literature reviews (Payne, et al., 2015a; Coughlin, et al., 2016; Covolo, et al., 2017; Jee, 2017). This may be because of Mateo, et al.'s (2017) small sample of seven clinical trial publications, which limits the pooled estimate results. The countering reviews had larger sample sizes: Payne, et al.'s (2015a) 24 papers; Coughlin, et al.'s (2016) 15 papers; Covolo, et al.'s (2017) 23 papers; and Jee's (2017) 10 papers. These four other reviews, however, followed systematic review methods, whereas Mateo, et al. (2015) performed both a systematic review and three meta-analyses, which highlights a gap in literature for larger sample meta-analyses on the effective potential of mHealth physical activity behaviour change intervention apps. Further discussions by Mateo, et al. (2015, p.e256) also emphasise the use and integration of psychology and behaviour change theory in designing effective apps, and that a limitation of their study failed to account for the apps' various design features, theory- and evidence-based behaviour change techniques and persuasive design strategies, all of which are "useful ... [for] increasing app appeal".

***Payne, et al. (2015a)***

In a systematic review conducted by *Payne, et al. (2015a)*, 24 studies released between 2007 and 2014 were examined with the dual-objective of determining the potential effectiveness of mHealth behaviour change intervention apps, and describing the BCTs and design features necessary for developing and delivering feasible, acceptable and efficacious app-based interventions. Ten of the 24 studies targeted physical activity as a primary measure, of which eight reported increases. Using self-reported measures elicited through either physical activity apps or questionnaires, four studies reported significant increases in physical activity (King, et al., 2013; Mattila, et al., 2013; Turner-McGrievy, et al., 2013; van Drongelen, et al., 2014), while one reported only a slight increase (Allen, et al., 2013). Utilising objective measures (from the smartphones' built-in sensor, accelerometer and GPS technologies), three studies (Bond, et al., 2014; Hebden, et al., 2014; Kirwan, et al., 2013) reported significant increases in physical activity. Two of the ten studies reported no significant or modest increases in physical activity (Turner-McGrievy, et al., 2011; Smith, et al., 2014). The authors stressed the need for more rigorous RCT studies with larger sample sizes and more research into evaluating and determining the utility of various intervention components and BCTs, as well as the improved design of app features that enhance app usability and ease of use, leading to better user retention and user acceptance rates (Payne, et al., 2015a). Nevertheless, overall, Payne, et al.'s (2015a) review argued for the potential effectiveness, feasibility and acceptability of mHealth physical activity behaviour change intervention apps in general.

***Muntaner, Vidal-Conti and Palou (2015)***

Another systematic review conducted by *Muntaner, Vidal-Conti and Palou (2015)* reviewed 12 publications released between 2003 and 2013, with the aim to summarise literature and investigate the effectiveness of mobile phones and smartphone apps primarily intended for physical activity behaviour change. Six of the articles reported significant increases in physical activity levels (Cheung, et al., 2008; Fjeldsoe, Miller and Marshall, 2010; Prestwich, Perugini and Hurling, 2010; Conroy, et al., 2011; David, et al., 2012; Kim and Glanz, 2013). Ten studies utilised one or more theoretical models in informing the physical activity apps' intervention components, BCTs and design features. These included Social Cognitive Theory (SCT), the Transtheoretical Model (TTM), Theory of Planned Behaviour (TPB), Goal Setting Theory, Problem Solving Theory and Protection Motivation Theory (Muntaner, Vidal-Conti and Palou, 2015). A notable limitation of Muntaner, Vidal-Conti and Palou's (2015) findings, however, is

their generalised review of all types of mobile phone and app intervention methods, including short messaging services (smses), text messages, personal digital assistants (PDAs) and voice message services; hence their review findings pertaining to physical activity apps exclusively was inconclusive. A systematic review conducted by Free, et al. (2013) exhibited the same limitation (including studies using smses, multi-media messages (MMSes), telephone calls, PDAs, and MP3 and MP4 functions), which further demonstrates the scarcity of literature reviews available on mHealth physical activity behaviour change intervention apps specifically. Free, et al.'s (2013) systematic review findings were, nevertheless, similar to that of Muntaner, Vidal-Conti and Palou's (2015) in that mHealth physical activity behaviour change intervention apps utilising the mobile platform have the potential to effect positive health behaviour change in individuals, although some study findings revealed mixed results.

There are a handful of other systematic and non-systematic literature reviews and meta-analyses in the current knowledge base, especially given the time lapse from when this critical review was initially conducted in early 2018 to present date in 2021. Nevertheless, these publications and summary findings reveal valuable findings pertaining to design challenges and the effectiveness of mHealth intervention apps, and apps specifically targeting the promotion of physical activity behaviour change.

#### 4.4.2.3 App-Specific Studies on the Design and Effectiveness of mHealth (Physical Activity) Behaviour Change Intervention Apps

A number of studies have been conducted on specific research and commercial mHealth (physical activity) behaviour change intervention apps. The studies included in this subsection either cover apps targeting solely physical activity, or targeting other health behaviours related to and along with physical activity, such as healthy eating and weight management interventions. These app-specific studies have often been empirical and user-orientated in nature and tend to discuss challenges, knowledge gaps and opportunities relating to the design and effectiveness of mHealth (physical activity) behaviour change intervention apps. The reviewed app-specific studies include (in no specific order): Recio-Rodriguez, et al. (2016); Recio-Rodriguez, et al. (2018); Alnasser, et al. (2016); Harries, et al. (2016); Harries, et al. (2013); Dallinga, et al. (2015); Direito, et al. (2015); Rabbi, et al. (2015); Casey, et al. (2014); Glynn, et al. (2014); Kirwan, et al. (2012a; 2012b); Turner-McGrievy and Tate (2011); Fukuoka, et al. (2010); and Martin, et al. (2015). The thesis main body discussion includes updated reviews dated 2019 to 2021.

***Recio-Rodriguez, et al. (2016)***

Under the *'Lifestyles and Arterial Aging' (EVIDENT)* study, a randomised, multicentre, double-blinded clinical trial *(EVIDENT II)* was carried out by *Recio-Rodriguez, et al. (2016)* to evaluate the effectiveness of adding a smartphone app to standard counselling sessions to increase physical activity and adherence to a Mediterranean diet following a three month intervention period. A total of 833 participants were selected from the EVIDENT I study (Recio-Rodriguez, et al., 2014) which included 1553 participants located across six primary care centres in Spain. Through randomised sampling, participants were split between two parallel groups: 415 in the app+counselling group, and 418 in the counselling only group (Recio-Rodriguez, et al., 2016). Primary outcome measures were changes in physical activity behaviour and adherence to the Mediterranean diet, and secondary outcomes measured anthropometric changes (including blood pressure, body mass index (BMI), waist circumference and laboratory parameters). Based on the smartphone app's accelerometer recordings and a questionnaire, the EVIDENT II results indicated a statistically significant increase in leisure-time moderate-to-vigorous physical activity in the app+counselling group (mean 29.95% increase, CI 5-53 min/week), but no statistically significant change in the counselling only group. Adherence to the Mediterranean diet increased in both groups. With regard to the physical activity intervention component, in the app+counselling group, 56.8% of the participants used the app for more than 60 days (Recio-Rodriguez, et al., 2016). Although there was a reported decrease in both groups' physical activity levels after the three-month trial period, the decreased app use was less pronounced in the 56.8% of participants that used the app most.

As a matter of interest, Recio-Rodriguez, et al.'s (2016) study results revealed that participants in this group (56.8% of app users) showed a new increase in time spent on moderate physical activity per week (mean 42.9 minutes/week), and a net increase in time spent on moderate-to-vigorous physical activity per week (mean 44.0 minutes/week). The results also indicated a net increase in step counts minutes per week (mean 766.6 counts minutes/week) and a net decrease in sedentary behaviour time per week (mean 126 minutes/week) (Recio-Rodriguez, et al., 2016). Overall, Recio-Rodriguez, et al. (2016) concluded that improved adherence to an app (in this case more than 60 days) appears to be associated with better results in terms of physical activity behaviour monitored with the smartphone app's accelerometer. They further concluded that the EVIDENT II study demonstrated the effective potential for a smartphone app (along with counselling sessions) to increase physical activity at various intensities, including low,

moderate and moderate-to-vigorous intensities, as well as simultaneously reduce sedentary behaviour (Recio-Rodriguez, et al., 2016).

***Recio-Rodriguez, et al. (2018)***

After the EVIDENT I and II studies, the *EVIDENT 3 app* was designed and developed by *Recio-Rodriguez, et al. (2018)* under the *EVIDENT III* or 3 trial. The evaluation results of a 12-month randomised controlled trial (RCT) of the EVIDENT 3 app was underway in 2018 and remains unpublished in February 2021. Nevertheless, similarly to the EVIDENT II study, a randomised, double-blinded, multicentre clinical trial was designed to be conducted with two parallel groups in primary care settings across five health centres in Spain (Recio-Rodriguez, et al., 2018). While the EVIDENT II smartphone app was intended for physical activity and the Mediterranean diet, the EVIDENT 3 app was primarily designed for weight loss, by targeting other healthy lifestyle behaviours including physical activity, caloric intake and sedentary behaviour (Recio-Rodriguez, et al., 2018). The study selected 700 subjects who were clinically classified as sedentary, and randomly assigned them to either an intervention group (in which participants were provided with the EVIDENT 3 app, a smart-band and pre-intervention counselling) or a control group (in which participants were provided with pre-intervention counselling only) (Recio-Rodriguez, et al., 2018).

The EVIDENT 3 app allows users to track, record, store and review data collected through both the smart-band and self-reported entries, and provided users with tailored recommendations and personalised targets based on their weight loss goals (Recio-Rodriguez, et al., 2018). The primary outcome measure was weight loss, but secondary outcomes measures included physical activity step-count, sedentary sitting time, caloric intake, quality of life, arterial aging, and pro-inflammatory markers (Recio-Rodriguez, et al., 2018). While the results are yet to be published in literature, the results of Recio-Rodriguez, et al.'s (2018) study will provide a valuable contribution to knowledge in that it entails the measuring and analysing the effectiveness of a smartphone app over a baseline, three-month and post-one year trial period. In comparison to this long-term (post-one year) trial duration, the majority of other mHealth physical activity app literature tend to measure health outcomes over a short-term trial period, spanning 6 weeks (Harries, et al., 2016) to 8 weeks (Dallinga, et al., 2015), 12 weeks (Recio-Rodriguez, et al., 2014), or six months (Turner-McGrievy and Tate, 2011; Allen, et al., 2013).

***Alnasser, et al. (2016)***

*Alnasser, et al. (2016)* conducted a study on the usability, validity and effectiveness of *Twazon*, a physical activity, weight loss and diet behaviour change research app, developed specifically for the Arabic population. With regard to the physical activity component of the app, recommendations suggested a minimum of 30 minutes of physical activity three times per week, and 10 000 steps per day tracked with a pedometer (Alnasser, et al., 2016). The app further allowed users to review and access their physical activity every two weeks, and provided users with tips when participants' physical activity levels were low (Alnasser, et al., 2016). Results from an expert healthcare professionals review and pilot study with users found the app to provide valid, accurate and necessary physical activity, weight- and diet-related information (Alnasser, et al., 2016). The expert review also found the app to meet the tailored preferences and needs of the target audience, and it was perceived by users as aesthetically pleasing and user-friendly; thus demonstrating usability (Alnasser, et al., 2016). Alnasser, et al. (2016) suggested that careful thought be given to the characteristics of specific target populations (such as in this case, which targeted Saudi Arabian women), and that changing trends and cultural norms be considered when designing effective mHealth behaviour change intervention apps with high usability. Overall, the Twazon *app* demonstrated usability, validity and effectiveness in creating awareness of and motivation towards increased physical activity participation and behaviour change.

***Harries, et al. (2016)***

*Harries, et al. (2016)* conducted an app-specific study aiming to measure the effectiveness of a mHealth physical activity behaviour change intervention research app, *bActive*, utilised by 165 young and middle-aged males (18-40 years old) over a six-week trial period. The randomised controlled trial (RCT) divided subjects into three groups: (1) no feedback, (2) personal individualised feedback, and (3) social group feedback, to compare differences in step counts. Smartphone apps providing continuous step-count feedback significantly increased physical activity by 60% and 69% in the individual and social feedback groups. These increases were in sharp contrast to the no feedback group. There, however, was no statistically significant difference between the results of the individual and social feedback groups. This lead to the conclusion that while mHealth physical activity behaviour change intervention apps can be effective in increasing walking (step-counts), the provision of individualised versus social feedback has no apparent incremental impact or significant difference (Harries, et al., 2016).

In Harries, et al.'s (2016) study, the social feedback group was based on a social norms approach, demonstrating the tendency for people to seek to conform to what they perceive to be normal physical activity behaviour of others – this aligns with social support theories discussed in Chapters 3 and 4. Harries, et al.'s (2016) results for the effective influence of social feedback provision coincides with other mHealth physical activity app-specific empirical result findings, such as *CoachMe* by Fadhil, Matteotti and Armellin (2016) and *Active2Gether* by Klein, Manzoor and Mollee (2017). In addition to Harries, et al.'s (2016) study, a few years prior, Harries, et al. (2013) conducted a study on the effectiveness of the bActive app with 152 male participants (ages ranging 22-40 years old) over a six week trial period. The results were similar to Harries, et al.'s (2016) results in that bActive successfully prompted users to increase their daily step-count by an average of 64%, yet the inclusion of social feedback based on social comparison theory was also not significantly different in relation to personal individualised feedback (Harries, et al., 2013).

***Vos, et al. (2016)***

*Vos, et al.'s (2016)* app-specific study was performed on a personalised mHealth physical activity behaviour change intervention research app called *Inspirun* – specifically targeting running. A series of three iterative design-test-refine cycles informed the design, development and evaluation of Vos, et al.'s (2016) Inspirun app, targeting runners clustered into four groups: (1) social competitive runners, (2) individual fitness runners, (3) individual competitive runners, and (4) social runners. This iterative and rapid design-test-refine cycle complements Johnston, et al.'s (2015) incorporation of the Plan, Do, Study, Act (PDSA) cycle (Taylor, et al., 2014) in their proposed Clarify, Design and Evaluate (CDE) Framework (included as one of the nine multi- and inter-disciplinary approaches in the thesis's main body discussion in Subsection 4.4.3). Qualitative research methods informed the Inspirun app's three iterative design cycles (Vos, et al., 2016). The first design cycle used focus groups to validate the four group running profiles, review the strengths and weaknesses of other existing smartphone apps for running, and identify desired design features deemed ideal for a running app (Vos, et al., 2016). The "essential" desired design features found were to: help people start and improve running in a fun and healthy way; offer personalised training schedules tailored to users' running profiles; ensure training schedules account for users' work-life balance; provide tailored feedback during running sessions; tailor and adjust every training session in consideration for a user's pulse (heart rate) reading, perceived intensity, and GPS data (location, distance, route, time); and to allow for easy, unobtrusive capturing of data for monitoring (Vos,

et al., 2016). The second design cycle involved five mind-mapping sessions with a multi-disciplinary team of professionals from multiple different fields of knowledge and expertise, including psychology, human movement sciences, industrial design and software engineering, to further define and refine the app's four running profiles and desired app design features. The third design cycle outlined the user requirements specifications, after which mock-up wireframes of the app's user interface screens were developed. Thereafter, three test-refine cycles were conducted in three user studies (Vos, et al., 2016).

Vos, et al.'s (2016) first user study (n=10 participants including experienced and inexperienced runners) used the Mobile Application Rating Scale (MARS) (Stoyanov, et al., 2015) tool to evaluate and gather users' feedback on *Inspirun version 0.1*, assessing functionality, engagement, aesthetics, information, and app specific features. Users' feedback informed the improved and refined design of *Inspirun version 0.2*, accounting for improvements to the accuracy of running data and information, the provision of auditory tailored feedback matching users' psychographic profiles, the option to pause and abort a training session, a clearer summary overview of a user's training session, and several other technical and design feature issues. The second test-refine cycle included a user study (n=6 experienced runners and researchers) that again used the MARS scale (Stoyanov, et al., 2015), along with open-ended questions, to gather feedback on further app design issues. The analysed feedback informed the refined design of Inspirun app version 0.3, whereby improvements were made regarding the app's provision of information and training feedback, interface navigation and some design adjustments (Vos, et al., 2016). The third user study conducted on *Inspirun version 0.3* focused on the MARS scale's fifth dimension (app specific features), revealing a few minor bug fixes, which then informed the refined design of *Inspirun version 1.0*.

A user evaluation study aiming to validate *Inspirun version 1.0* was reportedly planned for future investigation, using a quantitative intervention design would over 8 to 10 week trial period (including a completed minimum of 20 full training sessions) with approximately 100 participants. Users' levels of motivation, perceived benefits of running, and experienced use of Inspirun version 1.0 was to be monitored over the trial period. After which, another MARS study will be conducted with the same 100 participants (Vos, et al., 2016). The results of this quantitative study were not yet published when this preliminary critical review was conducted. Other publications were subsequently published on Inspirun (Dallinga, et al., 2018; Deelen, et al., 2018), and the latest publication in August 2020 changed the app name to *Inspirun e-Coach* (Janssen, et al., 2020).

***Dallinga, et al. (2015)***

*Dallinga, et al. (2015)* conducted a cross sectional study aimed at investigating the effectiveness of mHealth physical activity behaviour change intervention apps for recreational running by examining the relationship between the use of apps and changes in physical activity, health and lifestyle behaviour, and self-image of short and long distance runners. In comparison to the other app-specific studies discussed thus far, which were performed on mHealth physical activity research apps, Dallinga, et al. (2015) conducted their study on mHealth physical activity consumer apps that are available for download from commercial app market stores (such as Google Play and Apple App Store). A random selection of 2838 runners of a 6.4 km and 16 km recreational run in the Netherlands participated in the study (Dallinga, et al., 2015). Most participants used the *Runkeeper* app (44.4%) in their training preparation for the event, and 16.9% who used "other" physical activity apps, followed by *Nike+ iPod*, *Runtastic*, *Endomondo* and *Strava* apps, respectively (Dallinga, et al., 2015).

Dallinga, et al.'s (2015) online survey revealed the majority of app users to be female, and that app users tended to be significantly younger than non-app users, trained less frequently throughout the year, yet increased their training significantly when using the app to prepare for the running event (Dallinga, et al., 2015). Additional results of the study showed that for both the 6.4 km and 16 km app users, app use was positively associated with increased running activity and feeling healthier, and positively related to feeling better about themselves, feeling more like an athlete, motivating others to participate in running, and losing weight (Dallinga, et al., 2015). For the 16 km app users specifically, app use was positively associated with healthier eating, feeling more energetic and reporting a higher chance of maintaining their running physical activity and training in the future, which suggests apps are an effective intervention tool for decreasing drop-out rates for running participation (Dallinga, et al., 2015). Dallinga, et al. (2015) also discusses the social support and social media aspect of these major commercial running apps, explaining that Consumer Health Informatics (CHI) platform-mediated social interactions can lead to shared motivation, encouragement and support, and The Quantified Self movement (two terms and concepts that were defined in Appendix C.1 and Appendix C.2, respectively).

A valuable contribution of Dallinga, et al.'s (2015) study are the findings regarding the positive relationships between mHealth physical activity behaviour change intervention app use and users' perceived health and self-image in preparation for training for an event. These self-

perceptions and feelings should however take into account careful consideration of participants' baseline psychological and self-image factors. Another limitation concerns which unknown apps fall under the "other" app category of Dallinga, et al.'s (2015, p.5) survey; results which could further inform an understanding of the consumer-facing apps deemed popular by users within the recreational running communities. Also, while Runkeeper was found to be the predominately used app amongst participants, important to note is that physical activity apps differ in their features, integrated BCTs and persuasive software design principles. From these study findings, it can be concluded that the design of mHealth physical activity apps, and the way they present information, provide feedback, manage goal setting, progress and attainment, and ultimately persuade users to improve their running (and exercise) behaviour and health outcomes, all influences apps' effective potential, efficacy, usefulness and usability. Overall, Dallinga, et al. (2015) argue for the effective potential for the use of mHealth behaviour change apps in delivering physical activity promotion interventions for recreational running, and suggest further studies and RCTs into assessing the effectiveness of particular popular consumer apps, such as Runkeeper.

***Direito, et al. (2015)***

*Direito, et al. (2015)* performed a running and cardiorespiratory fitness study on the effectiveness of two commercial consumer market apps, *Zombies Run!* and *Couch-to-5K (formerly known as Get Running)*. Within the Apps for Improving FITness (AIMFIT) trial, insufficiently active healthy young people (ages 14 to 17 years) were allocated at random to one of three conditions: (1) use of the *Zombies, Run!*, an immersive app; (2) use of the *Get Running (Couch-to-5K)*, a non-immersive app; or (3) use of no app, a control group (Direito, et al., 2015). Both apps provided users with an eight-week training programme designed to improve fitness and ability to run 5 km. While both apps integrated self-monitoring, self-regulatory and feedback techniques, *Zombies, Run!*, unlike *Couch-to-5K*, incorporated game-themed design features (Direito, et al., 2015). Data was collected at baseline and at the end of the eight-week RCT period. The primary outcome was to measure cardiorespiratory fitness objectively by performing a time-to-complete 1-mile run/walk test, and secondary outcomes aimed to examine participants' physical activity levels (both self-reported and accelerometry), enjoyment, psychological need satisfaction, and self-efficacy, as well as the acceptability and usability of the two apps (Direito, et al., 2015). The app use retention rates were significantly high at 96% (Direito, et al., 2015). However, although the trial results revealed improved fitness in the two app groups (time-to-complete was -28.4 seconds shorter for *Zombies, Run!*, and -

24.7 seconds shorter for *Get Running (Couch-to-5K)*), there were no significant intervention effects for both the primary and secondary outcome measures in either of the app groups compared to the control group (Direito, et al., 2015). Direito, et al. (2015, p.e210) concluded that while their study on the effectiveness of "commercial apps as a stand-alone instrument" for increased physical activity had no significant effect on cardiorespiratory fitness, they insist the "future use of PA [physical activity] apps is promising and highlights a potentially important role of these tools in a multifaceted approach to increase fitness, promote PA, and consequently reduce the adverse health outcomes associated with insufficient activity".

***Rabbi, et al. (2015)***

*Rabbi, et al. (2015)* conducted a randomised two-group trial on a physical activity and healthy eating promotion research app called *MyBehaviour*, as part of a pilot study. The trial offered users (1) automatic and manual logging to track physical activity, user location and food intake, (2) automatically analysed activity and food logs to identify frequent and non-frequent behaviours, and (3) a standard machine-learning and decision-making algorithm that generates personalised, actionable and low-effort suggestions (Rabbi, et al., 2015). These suggestions were contextualised to the user's location, environment and past behaviour, and were further contextualised by asking users whether they wish to continue, avoid or apply small changes to their behaviour in helping them reach their goals (Rabbi, et al., 2015). Seventeen participants were randomly assigned to receive either the *MyBehaviour* app's personalised suggestions (9 subjects in the intervention group) or generic non-personalised suggestions (8 subjects in the control group) over a three-week trial period (Rabbi, et al., 2015). Rabbi, et al.'s (2015) study aimed to investigate the technical feasibility of personalised suggestions, provided through the automatic feedback feature of *MyBehaviour*, in motivating participants to increase their daily physical activity and eat healthier.

Rabbi, et al.'s (2015) trial quantitative results revealed the participants of the *MyBehaviour* app intervention group to walk significantly more (at an average 10 minutes more per day) in comparison to participants in the control group (Rabbi, et al., 2015). Furthermore, while 78% of the participants in the experimental group showed positive physical activity trends, 75% of the participants in the control group exhibited negative trends (Rabbi, et al., 2015). Qualitative face-to-face interviews with the control group subjects revealed the generic, non-personalised suggestions to be impractical and difficult to implement into their daily lives, whereas the intervention group subjects described the *MyBehaviour* app's personalised suggestions to be

actionable, context-sensitive and relevant to their lives, environment, location and past physical activity behaviour (Rabbi, et al., 2015).

In designing the *MyBehaviour* app's personalised suggestions, theoretical principles were drawn from three well-known and credible theories: (1) Social Learning Theory, (2) Social Cognitive Theory (SCT), and (3) the Fogg Behavioural Model (FBM) (Fogg, 2009) (Rabbi, et al., 2015). The first of these two theories derive from the field of psychology (originating from the Health Behavioural Sciences' perspective) and the third derives from the fields of persuasive technology and persuasive systems design (originating from the Information Systems' perspective). Based on the theoretical principles of the FBM (Fogg, 2009), *MyBehaviour* included features that provided users with cues and triggers to action (also known as prompts) of which the suggested actions required minimal effort and little motivation from users (Rabbi, et al., 2015). The perceived ability to both perform and complete these low-effort and low-motivation actions is thus simplified and facilitated by the app, making it easier for users to achieve small changes to their daily physical activity (and healthy eating) behaviour over time (Rabbi, et al., 2015). Moreover, the qualitative findings (generated through an in-trial web-based daily diary, post-study semi-structured interviews and post-trial survey) confirmed the provision of automatic, context-sensitive and personalised suggestions to be effective in persuading increase physical activity, particularly in instances where tailored suggestions offered are perceived as more actionable and in line with users' lives and preferences (Rabbi, et al., 2015). In essence, the results of Rabbi, et al.'s (2015) trial revealed the dietary component of the app's intervention to insignificantly effective, whereas preliminary evidence found the technical feasibility and effectiveness of *MyBehaviour* to positively change individuals' physical activity levels.

***Casey, et al. (2014)***

*Casey, et al. (2014)* performed a qualitative research study aiming to evaluate patients' experiences in using *Accupedo-Pro Pedometer*, a mHealth research app for physical activity promotion, embedded within the SMART MOVE randomised controlled trial (RCT). Through conducting semi-structured interviews with 12 participants, four themes emerged from the analysis. The first theme, "transforming relationships with exercise", described how smartphone apps can affect individuals' physical activity behaviour through a transformational process, which encompassed interlinks between awareness and knowledge, goal setting, feedback, rewards, control and focus, confidence and ownership (Casey, et al., 2014). The

second theme, "persuasive technology tools", highlighted the valuable and influential use of persuasive systems design (PSD) principles reduction, tailoring, suggestion, self-monitoring and conditioning as demonstrating effective potential, were evident in underlying mechanisms of the behaviour change transformation process, and were perceived and received favourably by app participant users (Casey, et al., 2014). The third theme revealed the significance of an app's usability, and that in the face of unfriendly and unpleasant design features and poor user interface design, users desire to utilise, interact and engage with an app are deterred, resulting in reduced adoption, acceptance and adherence to the app intervention (Casey, et al., 2014). The fourth theme, "cascade effect", uncovered the influence an app can have on motivating and effecting physical activity behaviour change in not only app users, but also the user's broader social environment (Casey, et al., 2014). For example, if a user shares their performed physical activity experiences with their families, friends, social circles and larger community, others are likely to feel motivated and encouraged to increase their physical activity levels. Casey, et al. (2014) concluded the effective potential of smartphone apps in promoting physical activity and their persuasive role in supporting and facilitating the transformational behaviour change process in individuals.

***Glynn, et al. (2014)***

*Glynn, et al. (2014)* evaluated the effectiveness of the *Accupedo-Pro Pedometer* app in an 8-week RCT in the same SMART MOVE trial as Casey, et al. (2014). Glynn, et al.'s (2014) app-specific study was conducted with 90 participants in three rural primary care practices in Ireland, and Android smartphone users aged 16 years and older were recruited for the study. Participants were provided with information on the benefits of exercise, were encouraged to obtain the popularised "10 000 steps a day" goal, and offered detailed instructions on how to use the app in achieving the primary goal (Glynn, et al., 2014). Over the 8-week period, the difference in the adjusted mean (average) demonstrated an increase of 1029 (95% confidence interval 214 to 1843) steps per day; proving evidence for the *Accupedo-Pro Pedometer* app's effective influence to significantly increase daily step-count, and hence increase individuals' physical activity levels (Glynn, et al., 2014). Glynn, et al. (2014) also emphasised the importance of behavioural change components and BCTs (such as the provision of tailored information, and feedback on performance through time, speed and energy consumption metrics) accompanied by PSD principles (such as rewarding goals achieved), along with attractive user interface graphic displays for enhanced user-engagement and usability. Another key point conveyed by Glynn, et al. (2014) is that health behavioural change is not only a job

for health scientists and that the design of effective mHealth apps are also largely related to and driven by innovations in technological/systems disciplines. This emphasises that mHealth apps are rapidly "becom[ing] an important driver for the behaviour change process ... [and that] such inexpensive, accessibly and user-friendly technologies should be considered a component of any future intervention to promote physical activity" (Glynn, et al., 2014, p.e390). Glynn, et al. (2014) also further support the argument made in Chapter 4's Section 4.4, highlighting the ongoing need for more collaborative multi- and inter-disciplinary efforts for improving the design, theory, development and evaluation of effective physical activity (health promotion) behaviour change (intervention) apps.

***Kirwan, et al. (2012a; 2012b)***

*Kirwan, et al. (2012a)* conducted a formative study on a mHealth iPhone (Apple) research app, *iStepLog*, which involved 12 Australian adults, aged 18 years and older (8 of which were women). Data gathered and analysed through usability questionnaires and semi-structured interviews, revealed four usability themes relating to app design, feedback, navigation and terminology. Similarly to the *Accupedo-Pro Pedometer* app (Casey, et al., 2014; Glynn, et al., 2014), Kirwan, et al. (2012a) suggested that users walk 10 000 steps every day, and provided the means to track, review and self-monitor their step-count. Kirwan, et al. (2012a) used usability studies and participants' usability feedback to iteratively design and improve iStepLog, which resulted in a reduction of problems experienced and a decrease in time required to complete tasks provided by the app (such as logging, syncing and editing their steps). Essentially, Kirwan, et al.'s (2012a) study emphasised the importance of performing iterative design-develop-evaluate cycles and quick formative user evaluations in the design of effective physical activity smartphone apps. This rapid and iterative cycle approach aligns with the multi- and inter-disciplinary development approaches reviewed and discussed in the thesis's main body discussion in Subsection 4.4.3. Namely *the CeHRes Roadmap* (van Gemert-Pijnen, et al., 2011), *the mHealth Intervention Development and Evaluation Process* (Whittaker, et al., 2012); *the Digital Intervention Development Approach* (Bradbury, et al., 2014); *the Clarify, Design and Evaluate (CDE) Framework* (Johnston, et al., 2015); *the IDEAS Framework* (Mummah, et al., 2016); and *the mHealth Intervention Development Process*(Smith, et al., 2016).

In addition to this formative usability study (Kirwan, et al., 2012a), *Kirwan, et al. (2012b)* conducted a matched case-control trial of the Accupedo-Pro Pedometer app over a three-month period. The three aims of the trial were to examine the effectiveness of the app on self-

monitoring and self-reporting physical activity levels, measure participants' perceived usefulness and usability of the app, and investigate the relationship between the app's perceived usefulness and usability and its actual use (Kirwan, et al., 2012b). The results showed the participants to use the app 71.22% of the time to log their daily steps (with the daily goal of 10 000 steps) (Kirwan, et al., 2012b). The regression analyses also revealed the use of the app to positively increase the likelihood of users logging and recording their daily steps, in comparison to those not using the app (Kirwan, et al., 2012b). Participants rated the Accupedo-Pro Pedometer app high in both usefulness and usability, although a linear regression analysis of the study results also revealed a non-significant relationship between the perceived usefulness and usability of the app and the frequency in which participants logged their daily steps (Kirwan, et al., 2012b). Overall, the app was deemed potentially effective in changing individuals' physical activity levels.

***Allen, et al. (2013)***

*Allen, et al. (2013)* conducted a study on the research and commercialised app, *Lose It!*, to evaluate its acceptability, feasibility and efficacy. The study was performed using a RCT with 68 obese adults to receive one of four interventions over a six-month duration: (1) intensive counselling intervention; (2) intensive counselling intervention plus smartphone intervention; (3) a less intensive counselling intervention plus smartphone intervention; and (4) smartphone intervention only. The outcome measures of weight, body mass index (BMI), waist circumference, and self-reported physical activity levels and dietary intake were assessed at baseline (Allen, et al., 2013). The results revealed the participants in the intensive counselling intervention plus smartphone intervention, and the less intensive counselling intervention plus smartphone intervention, to lose more weight in comparison to participants in the other two intervention groups (5.4 kg and 3.3 kg, respectively). Both the *Lost It!* app and the counselling session were based on an eclectic of psychology theories including social cognitive theory (SCT), behavioural self-management, and motivational interviewing (MI) counselling techniques (Allen, et al., 2013). In terms of the exercise component of the intervention, participants were encouraged to perform a minimum of 150 minutes of moderate to high intensity physical activity per week, in accordance with the WHO's (2010b;2020) physical activity guideline recommendations. The *Lose It!* app integrated design features and BCTs based on self-monitoring, self-management, mindful empowerment, and provided users with real-time feedback on performance as well as motivators and opportunities for social support through social networking (Allen, et al., 2013). The results of this pilot trial provided

preliminary evidence and support for the combined use of the smartphone app with both high and low intensive counselling sessions to effectively motivate frequent self-monitoring and increased physical activity engagement (Allen, et al., 2013).

***Turner-McGrievy and Tate (2011)***

*Turner-McGrievy and Tate (2011)* investigated the effectiveness of a trio-pronged podcasting, mobile communications support and mobile self-monitoring mHealth physical activity and healthy eating app, as part of the *In the Mobile Pounds Off Digitally (Mobile POD)* weight-loss RCT, which aimed to assist weight loss in adults (96 overweight men and women). Over a six-month trial period spanning 2010 to 2011, the weight loss did not differ between app users and non-app users, as the latter participants sought to self-monitor and track their physical activity levels and dietary intake through either a website or a paper journal (Turner-McGrievy and Tate, 2011). Non-app users relied on social support from friends, while app users relied on social support though online sources and communities. Later on, a post hoc analysis was conducted by Turner-McGrievy, et al. (2013) to assess the relationship between diet (mobile app, website, or paper journal) and physical activity (mobile app vs no mobile app) self-monitoring and dietary and physical activity behaviours. Adjusting for the randomised group and demographics, the physical activity app users self-monitored exercise more frequently over the six-month trial, and reported greater intentionally performed physical activity than non-app users (Turner-McGrievy, et al., 2013). After six months, the physical activity app users had a significantly lower body mass index (BMI) compared to non-app users. While no significant differences were found between app users and non-app users with regard to dietary intake, the use of a self-monitoring app showed to have a significant effect on participants' physical activity levels, and subsequently their weight and BMIs (Turner-McGrievy, et al., 2013).

There are a handful of other app-specific study publications in the current knowledge base, especially given the time lapse from when this critical review was initially conducted in early 2018 to present date in 2021. Nevertheless, these publications and summary findings reveal valuable findings pertaining to design challenges and the effectiveness of mHealth intervention apps, and apps specifically targeting the promotion of physical activity behaviour change.

#### 4.4.2.4 Consumer App Market Reviews on the Design and Effectiveness of mHealth (Physical Activity) Behaviour Change Intervention Apps

Of the two sub-section reviews thus far, minimal references have been made to commercial consumer apps, which are available for public download on app market platforms such as the Google Play Store and the Apple App Store. In light of this knowledge gap, additional literature-based consumer app market review were conducted on particular groups or clusters of commercialised, publicly available mHealth physical activity consumer apps selected from the "Health and Fitness" category (discussed in Section 4.3). For the most part, these consumer app market reviews aim to examine, analyse and evaluate the utilisation and presence of theoretical models and constructs, BCTs, design features, PSD principles in popular mHealth physical activity behaviour change intervention consumer apps. A notable number of commercial consumer app reviews also aim to investigate and determine the general feasibility, efficacy and effectiveness of these publicly downloadable apps, as well as explore users' perceptions, views, preferences and opinions on the BCTs and design features present in these consumer apps. As discussed in the thesis's main body discussion in Section 4.3, some of the popular commercial consumer app market physical activity and fitness apps include: *MyMyFitness*, *Endomondo*, *Runkeeper*, *Jawbone*, *Nike+ (Running Club and Training Club)*, *Strava*, *Runtastic*, *Couch-to-5K*, and many thousands more. The summary findings of literature's most frequently cited, high-quality and reliable consumer app market reviews (as to date in 2017) will be discussed below. The consumer app market reviews discussed in this subsection include (in no particular order): Bondaronek, et al. (2018); Schoeppe, et al. (2017); Bardus, et al. (2016); Frie, et al. (2017); Vaquero (2016); Modave, et al. (2015); and Knight, et al. (2015).

***Bondaronek, et al. (2018)***

*Bondaronek, et al. (2018)* conducted a review and content analysis on 65 of the most popular, publicly available physical activity smartphone apps downloaded from the two leading consumer app markets, namely the Google Play (for Android) and iTunes (for Apple) app stores. Bondaronek, et al.'s (2018) study aimed to evaluate the quality of these apps by assessing: (1) the safety of users' data (privacy and security); (2) the likelihood of effectiveness (the presence of behaviour change techniques, the use of theoretical frameworks and constructs, and the quality of the development and evaluation processes used in designing the physical activity apps); and (3) users' experiences of the apps (user ratings and usability). In terms of

the first study aim, safety, 70% of the apps offered a privacy policy, and 80% reported collecting personal identifiable information and health data, yet only 40% described how users' data would be protected, and more concerning, most of the apps were found to have breached users' privacy and security policy agreements (Bondaronek, et al., 2018). With regards to the second study aim, the likelihood of effectiveness, Bondaronek, et al.'s (2018) use of Michie, et al.'s (2013) Behaviour Change Technique Taxonomy v1 revealed an average presence of 7 (SD=2.9) (of a possible 93) BCTs, and every app was found to contain at least one BCT. Although the maximum of 12 and 13 techniques identified in one free (*One You Couch to 5K*) and one paid (*7 Minute Workout Pro*) app, respectively (Bondaronek, et al., 2018).

Bondaronek, et al.'s (2018) study findings revealed the most frequently incorporated BCTs presented by the v1's technique groups were (as a percentage of the 65 apps): "feedback and monitoring" (predominantly "feedback on behaviour" and "feedback on outcome(s) of behaviour") (92%); "goals and planning" (predominantly "goal setting" and "action planning") (85%); "comparison of behaviour" (predominantly "demonstration on the behaviour") (66%); "social support" (64%); "shaping knowledge" (60%); "reward and threat" (53%); and "associations" (46%) (Bondaronek, et al., 2018). Of the "reward and threat" v1 technique group, "social reward" and "non-specific reward" were common (Bondaronek, et al., 2018). The apps with 11 techniques were: *7 Minute Workout*, *Freeletics Bodyweight – Workout*, *7 Minute Workout Challenge*, and *CARROT Fit*; with 10 techniques were: *Fitbit*, *Pacer*, *Adidas Trail & Run*, *Running for Weight Loss Pro*, *Couch-to-5K* (0K to 5K run training), *iMuscle 2*, *MapMyFitness*, *5K to 10K*, and *10K Pacer*; and with 9 techniques were: *Adrian James 6 Pack Abs Workout*, *Full Fitness*, *Runtastic PRO*, *Couch-to-5K* (running app and training coach), *Push Ups 0 to 100*, and *Starting Strength* (Bondaronek, et al., 2018).

With respect to the use of theory, Bondaronek, et al. (2018, p.11) emphasises "the use of evidence and theoretical frameworks is vital in developing [physical activity app] behaviour change interventions", yet only makes mention of the COM-B Model (Michie, et al., 2011). Under the second objective for likelihood of effectiveness, Bondaronek, et al.'s (2018) study findings regarding the quality of app development and evaluation approaches utilised by physical activity app designers revealed that only 12 of the apps' design and content were developed in consultation with experts. There were 12 apps associated with peer-reviewed journal publications and none of the apps reported any user involvement throughout the design, development or evaluation processes (Bondaronek, et al., 2018). In accordance with the discussion in the thesis's main body discussion in Section 4.4, and specifically Subsection 4.4.3,

Bondaronek, et al. (2018, p.11) argues for the "inclusion of multi-disciplinary skills and perspectives". This underlines the value and importance of adopting a multi- and inter-disciplinary, collaborative team approach that involves both user-cantered design processes (by involving users and conducting usability and user experience studies) and pragmatic randomised controlled trials (RCTs). This suggests the integration of design, development and evaluation approaches and methods from both the Information Systems and Health Behavioural Sciences perspectives, respectively, and reiterates and reinforces the argument for the need for "holistic" approaches. Moreover, Bondaronek, et al. (2018) also stress the need for higher quality approaches, processes and methods for guiding the design, development and evaluation of physical activity apps, and health behaviour change (intervention) apps in general.

Bondaronek, et al. (2018) study's third objective revealed generally good usability and positive user experiences for the reviewed commercial consumer market apps. Users' experiences, the use of the well-known, frequently-applied and verified System Usability Scale (SUS) yielded what can be described as an "excellent" average score of 83.4% (median=86.3%) for the 65 apps reviewed, of which 25% of the apps scored above 75%, and 50% of the apps scored between 75% and 92.5% (Bondaronek, et al., 2018). In addition to these scores, a review of users' app ratings found a high median rating of 4.5/5 and 4.4/5 for Google Play and iTunes physical activity apps, respectively. In terms of user experience, Bondaronek, et al. (2018, p.11) emphasises the relevance and significance of "high-quality graphic design, visual appeal, and ease of use [as] more likely to attract potential customers [that is, app users]" and that there is evidence for apps with higher usability as demonstrating more active user engagement and increased likelihood for effective intervention potential. On another note, a strength of Bondaronek, et al.'s (2018) review and content analysis is their exclusive focus on publicly available, consumer market apps targeting primarily and specifically physical activity. Furthermore, another strength is Bondaronek, et al.'s (2018) explicit exclusion of apps focused on multiple behaviours, alongside physical activity (such as healthy eating and weight management), and their categorising of apps into types of physical activity (including categories for: running programmes, tracking of running, workouts/bodyweight training/strength training, pedometers, and interval timers). Whereas the majority of other literature reviews and consumer app market reviews, in comparison to Bondaronek, et al. (2018), tend to include multi-purpose apps, which focus on physical activity, thereby limiting the valuable insights that can be drawn from such literature when attempting to investigate and understand mHealth physical activity behaviour change intervention apps in particular.

***Schoeppe, et al. (2017)***

*Schoeppe, et al. (2017)* conducted a systematic review on 25 commercial, mHealth Android and Apple consumer apps with the aim to (1) evaluate the apps' quality and content, and (2) examine the relationships between these quality ratings and the number of app design features and BCTs incorporated in the apps. The app review focused on health promotion behaviour change apps intended for children and adolescents (ages 2 to 18 years), and of the 25 apps selected for inclusion, 18 targeted physical activity, 12 targeted diet, and 7 addressed sedentary behaviour. Using Mobile App Rating Scale (MARS) (Stoyanov, et al., 2015), the overall app quality was moderate (mean=3.6, SD=0.6) with "functionality" scoring the highest (mean=4.1, SD=0.6), followed by "aesthetics" (mean=3.8, SD=0.8) and "engagement" (mean=3.6, SD=0.7), while "information quality" scored the lowest (mean=2.8, SD=0.8) (Scoeppe, et al., 2017). Using the Behaviour Change Technique (BCT) taxonomy, CALO-RE, an average of 6 techniques (of a possible 26) were identified in the apps (range 0-14) (Scoeppe, et al., 2017). The most frequently applied BCTs were, namely: "instructions" (n=19), "general encouragement" (n=18), "contingent rewards" (n=17), "feedback on performance" (n=13), "prompt self-monitoring behaviour" (n=12), and "opportunities for social comparison" (n=10). The mHealth consumer apps with the highest number of BCTs were *Zombies, Run!* (n=14), *Kubro* (n=12), *iBitz* (n=10) and *NFL Play* (n=10).

Scoeppe, et al. (2017) findings further revealed positive correlations between the number of BCTs included in apps and the total MARS score, specifically regarding "engagement" and "information quality". The "functionality" and "aesthetics" scores, however, were found to have no significant association with the number of BCTs (Scoeppe, et al., 2017). The number of BCTs was also positively associated with the number of app technical and design features. For mHealth apps in general, Scoeppe, et al. (2017) argues for the incorporation of theory- and evidence-based BCTs and the consideration for app technical and design features. This conclusion was drawn from their positive correlations with higher MARS ratings, and the improved perceptions of an app's engagement, functionality and aesthetics, which tends to lead to continuous and repeated app use, ultimately leading to app effectiveness and positive health behavioural change outcomes.

Schoeppe, et al. (2017) further emphasises the need to "foster effective communication and collaboration between health behaviour change researchers and app developers to set clear expectations about the app design and [to] learn from each other". This contributes to the

ongoing argument for the need to bridge the divide between researchers and practitioners from both the Health Behavioural Sciences and Information Systems perspectives, and that both sides are necessary for advancing and progressing the design, development and evaluation of effective mHealth (physical activity) behaviour change intervention apps.

***Bardus, et al. (2016)***

*Bardus, et al. (2016)* conducted a consumer app market review of the 23 most popular Andoird and Apple commercial weight management apps, which included targeting physical activity, healthy eating and weight management. Bardus, et al. (2016) aimed to analyse the engagement, functionality, aesthetics, information quality and BCTs of these mHealth consumer apps. Similarly to Schoeppe, et al.'s (2017) app review, Bardus, et al. (2016) used the MARS scale (Stoyanov, et al., 2015) to assess the quality of the 23 apps. The MARS final score yielded an average quality rating of 3.1 (SD=0.8) with "functionality" scoring the highest (mean=3.8, SD=0.9), followed by "aesthetics" (mean=3.4, SD=1.2) and "engagement" (mean=3.0, SD=0.9), while "information quality" scored the lowest (mean=2.2, SD=0.7). These results reflect similar MARS scores to Schoeppe, et al.'s (2017) findings.

Bardus, et al. (2016) further found the mHealth consumer apps to include 24 of the BCTs in the CALO-RE and v1 BCT taxonomies. On average, the apps included 10 BCTs (range 1-17) (Bardus, et al., 2016). The most frequently incorporated BCTs were "self-monitoring of behaviour" (n=20), "self-monitoring of outcomes" (n=19), "goal setting (outcome)" (n=19), "feedback on outcomes" (n=17), "feedback on behaviour" (n=16), "review outcome goals" (n=15), "goal setting (behaviour)" (n=13), "social support" (n=11) and "review behaviour goals" (n=10). A few valuable findings of Bardus, et al.'s (2016) review highlighted the positive correlation between the quality of apps, and their included number of BCTs (such as self-monitoring and goal setting) and app technical and design features (such as manual or automatic tracking, social media sharing, app reminders, logins and passwords). These findings once again, correspond to and support Schoeppe, et al.'s (2017) findings.

Bardus, et al. (2016) further found that apps that provided users with tracking features used significantly more BCTs than apps that did not offer tracking. They also found that automated tracking functionality scored significantly higher in aesthetics, engagement and the overall MARS ratings (Bardus, et al., 2016). Moreover, the study findings indicated that apps offering BCTs (self-monitoring, goal-setting and feedback on performance) were frequently associated

with increased physical activity and app intervention effectiveness, and also tended to score scored higher in the MARS "information quality" category, as well as enhance the perceived "functionality", "aesthetics" and "engagement" of apps (Bardus, et al., 2016). Bardus, et al.'s (2016) review findings are relevant and useful in that they further support the argument for the necessary integration of theory- and evidence-based BCTs, and the positive impact well-designed app features have on enhancing the usability, engagement, quality and overall effectiveness of mHealth physical activity behaviour change intervention apps.

***Frie, et al. (2017)***

*Frie, et al. (2017)* conducted a consumer app market study that aimed to assess and thematically analyse the design features of 15 weight loss and weight tracking apps by examining qualitative feedback provided through 569 users' app reviews on the Google Play Store (for Android smartphones and tablets). Although Frie, et al.'s (2017) review focused on apps primarily targeting weight loss and weight tracking, physical activity and healthy eating were the two core intervention approaches used in providing users with behavioural strategies, information content and prescriptive help in promoting, motivating and facilitating the weight loss/tracking process. Somewhat similar to the review findings of Schoeppe, et al. (2017) and Bardus, et al. (2016), Frie, et al.'s (2017) findings revealed the number of BCTs and design features to be significantly positively correlated with users' app ratings, the number of app reviews, and the number of app downloads.

Frie, et al. (2017), however, unlike the other two reviews (Bardus, et al., 2016; Schoeppe, et al., 2017), based the review on BCTs from the Oxford Food and Activity Behaviours (OxFAB) taxonomy (comprising 23 domains for classifying self-help weight loss intervention components) (Hartmann-Boyce, et al., 2016), rather than the BCTs taxonomies. Frie, et al.'s (2017) analysis of the 15 apps' user reviews revealed users to highly value BCTs providing self-monitoring, positive reinforcement, feedback on behaviour and goal progress, goal setting, planning (content and scheduling), prescriptive help and suggestions, quality information, prompts and reminders, and motivational strategies and support (Frie, et al., 2017). In terms of app design features, the most frequent positive user review comments (or comments suggesting and demanding design feature improvements) related to self-monitoring, graphical feedback visualisations, target line graphs, feedback goals, prediction target dates, and trend line graphs (Frie, et al., 2017).

Frie, et al. (2017) further highlight that since weight, physical activity and healthy eating data is for the most part of a personal and emotional nature, it is important that data portrayed through apps' interfaces is well designed, clear, simple and intuitive, and they further stress that the apps should offer users pleasurable visualisations and graphical representations. Both of these key points are positively associated with enhancing users' feelings (towards the app and health behaviour change) and the users' perceived sense of motivational support and comfort (which is offered through the apps) (Frie, et al., 2017). Technical features frequently commented (as either positive or needing improvement) related to syncing with Google Drive and Google Fit, backup to cloud functionality, and data import/export options (Frie, et al., 2017).

Additional findings of the thematic analysis revealed users to value apps that are simple and easy to use (providing key features, intuitive interfaces, and no clutter), provide smooth functionality (with high-quality version updates), and offer long-term app usage (which meets their personal preferences and needs) (Frie, et al., 2017). Importantly, these app technical and design features are positively associated with users' acceptance, adoption, usage, satisfaction and retention rates (Frie, et al., 2017). Whereas, in comparison, the presence of design and technical feature issues lead to user frustration and discontinued app usage. These findings further demonstrate the relevance and role of app technical and design features, along with evidence-based theoretical constructs, BCTs and PSD principles, in influencing and enhancing the potential for apps to successfully support and facilitate individuals through health behaviour change processes.

***Vaquero (2016)***

*Vaquero (2016)* conducted a consumer app market review of 20 popular fitness apps with the aim to analyse usability and user experience problems and issues pertaining to the motivational factors and app design features. Vaquero (2016) considered the type of target users based on fitness level and experience (beginners, intermediate and advanced exercisers) and divided apps between two groups based on their main functionality. The two groups included: (1) 14 fitness apps (main aim is to help and guide users on how to perform physical activities such as running, walking or working out with equipment), and (2) 6 tracking apps (main aim is to help the user track different aspects of their wellbeing including physical activity, diet, sedentary behaviour, sleeping time, heart rate). Some of these popular consumer market apps reviewed by Vaquero (2016) included: *Nike+ Training Club*, *Runtastic*, *FitStar Personal Trainer*, *Fitnet*, *Sworkit*,

*StrongLifts 5x5*, *Pump Up*, *Couch-to-5K*, *Charity Miles*, *Fitocracy*, *MapMyFitness*, *Endomondo*, *MyFitnessPal*, and *Noom Coach*. These apps are mentioned in the thesis's main body discussion in Section 4.3; all of which are reported as leading fitness apps according to Global Fitness App Market reports (Technavio, 2017; Orbis Research, 2017).

Vaquero (2016) found that, with regard to app design features and motivational factors, of the 14 fitness apps reviewed, ten apps did not include a calendar feature (which helps users monitor and check physical activity participation over time), nine apps did not offer feedback on performance, eight apps failed to provide follow-up on goals, six apps excluded the provision of feedback from a real or virtual personal trainer, and five apps did not include guiding exercise videos. A usability issue was the excess provision (overload) of information content both on the main app screen and in the glanceable displays (Vaquero, 2016). Additional usability issues related to other navigation and button interactivity issues, a lack of help and documentation for using and navigating the app, and that the way information and exercise content was displayed on some apps was confusing for users to follow (Vaquero, 2016). Motivational issues included the lack of functionality to create custom and personalised workouts, inability to track and monitor the number of repetitions and sets performed per exercise, and the limited types of exercises (Vaquero, 2016). These usability problems and motivational and design feature issues largely influence the persuasive potential, user engagement, user acceptance, app adoption and continued use of apps over time, and ultimately hinder the potential effectiveness and success of mHealth intervention apps to positively motivate and support individuals to change their physical activity behaviour.

In light of these identified issues, Vaquero (2016) suggests that designers and researchers work together to improve the motivational design and usability of physical activity apps. Vaquero (2016) also recommends that consideration be given to persuasive technology theories and models (such as the Fogg Behaviour Model (Fogg, 2009)), PSD principles (such as Consolvo, et al.'s (2009) eight strategies), and design feature guidelines for habit formation (such as those proposed by Stawarz, et al. (2015)). Vaquero (2016) further suggests using mobile app-based design feature strategies and guidelines (such as Ahtinen's (2015), gamification physical activity app-based design features (such as van Dyck's (2017)), and evidence-based health behaviour change theories (such as SCT, Self-Efficacy Theory, Self-Regulation Theory, SDT, Social Support Theory – all of which are detailed in the thesis's main body discussion in Chapter 3).

***Modave, et al. (2015)***

*Modave, et al. (2015)* conducted a systematic review of 30 popular mHealth physical activity Andoird and Apple consumer apps to analyse whether the apps' in-built exercise programmes were based on sound physical activity principles and recommended guidelines, and whether the apps' programmes catered for users' various fitness levels (generally categorised into beginner, intermediate and advanced exercises). Based on the American College of Sports Medicine's (ACSM) guidelines, a weighted scoring method was developed to generate sub-scores for the apps' quality of programme content using the key training elements for frequency, intensity, time and type (FITT) principle (Modave, et al., 2015). The types of exercise reviewed and scored included aerobic exercise (0-6 point scale), resistance and strength training (0-6 point scale) and flexibility (0-2 point scale), and these sub-score totals generated an overall quality score (0-14 points) for the fitness apps reviewed. Modave, et al.'s (2015) use of the ACSM's categories for exercise types and intensity levels align with the WHO's (2010b; 2020) physical activity guideline recommendations (discussed in the thesis's main body discussion in Chapter 3).

Modave, et al.'s (2015) review paid particular attention to whether the exercise programmes offered by the 30 apps provided adequate, accurate information for users at a beginner's fitness level. Of the 30 apps reviewed, the results revealed 17 to meet the ACSM's aerobic activity principles, and 27 to meet the resistance/strength training principles; however, 20 apps failed to meet the ACSM's flexibility principles (Modave, et al., 2015). Of the 30 apps, only 3 apps (*Sworkit Lite Personal Trainer, Couch-to-5K, Running for Weight Loss: Interval Training*) scored above 50% on the aerobic criteria; four apps (*Sworkit Lite Personal Trainer, Ultimate Fitness Free, JEFIT Workout, StrongLifts 5x5*) scored above 50% on the resistance/strength training criteria; and none of the apps scored above 50% on the flexibility criteria. The *Sworkit Lite Personal Trainer* app scored the highest overall for quality (9.01/14 points).

Modave, et al.'s (2015) systematic mHealth app consumer market review overall revealed that despite the large number of commercial fitness and physical activity apps available on the commerical market app stores, very few of them provide evidence-based exercise programmes with high-quality, accurate prescriptive training information. This indicates that a large portion of publicly available commercial mHealth physical activity consumer apps tend to neither provide users with adequate information and support on how to choose exercise programmes appropriate to their personal fitness levels, nor provide safe and reliable training plans

personalised to users' needs (Modave, et al., 2015). Of further concern is that apps providing insufficient and inadequate fitness coach training increases the risk that novice exercisers (beginners) will attempt to participate in exercise programmes when they most likely lack the appropriate physical preparedness, and the awareness of good technique and posture, ultimately adding to the threat of possible injury and harm. This study highlights the need for higher-quality commercial fitness coaching and exercise training apps informed by evidence-based physical activity guidelines and fitness/training principles.

***Knight, et al. (2015)***

*Knight, et al. (2015)* conducted a primary review on the descriptions of 379 physical activity apps to identify the articulated use of and adherence to the WHO's (2010b) physical activity guideline recommendations (discussed in the thesis's main body discussion in Chapter 3). To examine beyond the apps' descriptions, a secondary detailed review was conducted on a subset of 26 physical activity apps (of which 6 were endorsed, 10 were top-rated, and 10 were randomly selected). This secondary detailed review aimed to identify the presence of or reference to the WHO's (2010b) physical activity guidelines within the apps, and to identify potentially influential design and technological features in physical activity apps. The primary descriptive review results revealed none of the 379 apps adhere to aerobic activity guidelines, while seven implemented resistance/strength training guidelines.

Knight, et al.'s (2015) the secondary detailed review, however, revealed one app that referenced the WHO's (2010b) physical activity guidelines, four apps that were designed based on physical activity reports, and two apps were designed based on app developers' personal training/exercise knowledge and expertise. Additional secondary review findings found a number of apps to include design features for social networking (54.6%), setting physical activity goals and targets (30.9%) and a calendar to schedule physical activity (24.5%), and other technological design features, which allowed for the measuring of health parameters (36.7%) and for app pairing with peripheral devices (16.1%) (Knight, et al., 2015). Overall, Knight, et al.'s (2015) app review findings correspond with Modave, et al.'s (2015) in that there is a shortage of consumer mHealth physical activity apps on commercial app market stores (both Google Play and Apple App Stores) that offer evidence-based physical activity recommendations and fitness/exercise guidelines.

There are a handful of other consumer app market reviews in the current knowledge base, especially given the time lapse from when this critical review was initially conducted in early 2018 to present date in 2021. Nevertheless, these publications and summary findings reveal valuable findings pertaining to design challenges and the effectiveness of mHealth intervention apps, and apps specifically targeting the promotion of physical activity behaviour change; all of which informs the key points provided in the thesis's main body discussion in Chapter 4, Subsection 4.4.2 and Subsection 4.4.3.

#### 4.4.2.5 Other Publications on the Design and Effectiveness of mHealth (Physical Activity) Behaviour Change Intervention Apps

This final Subsection 4.4.2.5 includes a range of various other relevant publications. Given the number of publications cited, unlike the prior Subsections 4.4.2.2 to 4.4.2.5, a list of authors is not provided. Instead, this last subsection identifies a variety of physical activity apps and critically discusses mHealth physical activity behaviour change intervention app literature relating (but not limited) to several themes. These themes include: (1) underlying theories used in the design of physical activity app (including theories from psychology, health behaviour change, persuasive technology); (2) BCTs; (3) PSD principles; (4) design and technical app features (particularly regarding the translation and operationalisation of BCTs and persuasive principles); (5) users' perceptions (subjective opinions, views, attitudes, emotions and experiences); (6) user interface design, usability and user experience; and (7) brief mentions of approaches, processes and methods used to inform the design, development and evaluation of mHealth physical activity behaviour change intervention apps. The essence of the argument in this subsection's discussion concerns the relevance and significance of these themes in relation to the design, development and evaluation of effective and persuasive mHealth physical activity behaviour change intervention apps. Throughout this subsection's discussion, mHealth physical activity apps are identified (by name and cited) and both the Health Behaviour Sciences and Information Systems perspectives are considered.

Literature from both the Health Behavioural Sciences and Information Systems perspectives largely advocate for the use of evidence-based theories to inform the design, development and evaluation of effective mHealth physical activity behaviour change intervention apps (Dahlke, et al., 2015; Payne, et al., 2015a; Fanning, 2016; Hamper, et al., 2016; Haque, et al., 2016; Vaquero, 2016; Vos, et al., 2016; Voth, et al., 2016; Herrmann and Kim, 2017; Paul, et al., 2017; Schoeppe, et al., 2017; König, et al., 2018; Zhou, et al., 2018). These theories and their

theoretical constructs stem from various contributing and relevant multi-disciplinary fields (including psychology, health behavioural sciences, health sciences, persuasive technology and PSD, and information systems). Essentially, these theories and constructs "underpin" (Dute, Bemelmans and Breda, 2016, p.8) and "underlie" (Dahlke, et al., 2015, p.13; Moller, et al., 2017, p.88, 90) the design of mHealth physical activity behaviour change intervention apps. In other words, these theories and constructs help inform the design of intervention components, mechanisms of action, BCTs, PSD principles and the app design (interface) features with which users' interact and engage with through using the apps. There are several theories and theoretical constructs which have repeatedly been argued for in literature as relevant and valid for the design of mHealth physical activity apps, and have proven to be efficacious and effective in demonstrating a positive influence on individuals' physical activity behaviour. The frequently cited, applied and empirically-tested theories and theoretical constructs stemming from (individual, cognitive, behavioural, socio-behavioural, social) psychology include (but are not limited to): Social Cognitive Theory (SCT); Self-Efficacy Theory; Self-Determination Theory (SDT); Self-Regulation Theory; Theory of Planned Behaviour (TPB); Theory of Reasoned Action (TRA); Goal Setting Theory (GST); Health Belief Model (HBM); the Transtheoretical (Stages of Change) Model (TTM); the Elaboration Likelihood Model (ELM); Motivation Theories; and Social Support Theories. Many of these theories, models and constructs originate from the field of psychology, and more specifically health psychology. These theories were also identified and discussed in the thesis's main body discussion in Chapter 3 for demonstrating evidence as notable theories for informing the design of physical activity (health promotion) behaviour change interventions targeting the dual intra-interpersonal socioecological level.

From the Health Behavioural Sciences perspective, literature frequently reports the use of behaviour change models (such as the Behaviour Change Wheel and COM-B Model) and more specifically the two BCT taxonomies (Abraham and Michie, 2008; Michie, et al., 2011; 2013) as significantly valuable in informing the design of effective physical activity apps. These models and taxonomies incorporate theoretical constructs from the above-mentioned theories and theoretical models.

From the Information Systems perspective, some persuasive technology and PSD models identified in literature as being used to inform the design of mHealth physical activity apps include (but are not limited to): Fogg's Behavioural Model (FBM); the PSD (Process) Model (PSDM); Behaviour Chance Support System (BCSS) Theory; the Outcome/Change Matrix; the

Design with Intent Method (DwI); 3D-RAB Model; and other proposed persuasive design strategies and principles (Consolvo, et al., 2008; Consolvo, et al., 2009; Consolvo, McDonald and Landay, 2009; Consolvo, et al., 2012; Kelders, et al., 2015). Other theories from the Information Systems perspective frequently relate to users' acceptance, adoption, adherence and usage of physical activity apps; users' perceptions and subjective interpretations of physical activity apps' aesthetic and interactive design features, functionalities and intervention techniques; as well as the overall usability and user experience of physical activity apps. The information systems theories and models often utilised in the design, development and evaluation of physical activity apps include (but are not limited to): the Technology Acceptance Model (TAM); the Unified Theory of Acceptance and Use of Technology (UTAUT) Model or UTAUT; as well as traditional (Nielsen, 1990; 1994; ISO, 2002; Shneiderman and Plaisant, 2010) and more recently-proposed mobile and app-specific (for example: Brown, et al., 2013; Harrison, Flood and Duce, 2013; Kasali, et al., 2017) usability models and testing methods.

With regard to the use and application of theories, models and constructs, several physical activity apps can be identified in literature. For example, physical activity apps based on Social Cognitive Theory (SCT) include: *PersonA* (Al Ayubi, et al., 2014); *Balanced* (Duncan, et al., 2016); *BeWell24* (Buman, et al., 2016); *CityU Walk* (Wong and Kwok, 2016); *Active Team* (Edney, et al., 2017); as well as *Runkeeper, Strava, Runtastic* and *Endomondo* (Ploumen, 2016). Apps utilising social support theories and constructs include: *BeWell* (Rabbi, et al., 2011); *Cardio Trainer, Social Sport* (Weng, et al., 2013); *HealthyTogether* (Chen and Pu, 2014); *BikeTogether* (Chen and Lee, 2015); *iBurnCalories* (Khatri, 2015); *Pocket Yoga* (Ingber, 2015); *Ubersense* (Martin, Melnyk and Zimmerman, 2015); *iGo* (Haque, et al., 2016); *MyFitnessPal* (Zhao, Freeman and Li, 2016); *bActive* (Harries, et al., 2017); *Starfish* (Paul, et al., 2017); *Strava* (Smith and Treem, 2017); along with *Nike+ Running Club and Training Club*, *Endomondo*, *Runkeeper*, *Everywhere Run*, *Everywhere Race*, *Fitocracy*, *Strava Cycling*, *Noom CardioTrainer* and *Nexercise* (Middelweerd, et al., 2014; op den Akker, 2014). Other theories, models and constructs used in the design and development of physical activity apps include: Self-Determination Theory [*iGo* (Haque, et al., 2016) and *CityU Walk* (Wong and Kwok, 2016)]; Self-Regulation Theory [*MPTrain* and *TripleBeat* (op den Akker, 2014)]; the Transtheoretical Model [*UbiFit Garden* (Consolvo, et al., 2009); *ePass*, *eVIP*, *eSIYP* and *eTIYP* (Dute, Bemelmans and Breda, 2016)]; and Goal Setting Theory [*Chick-Clique* (Toscos, et al., 2006; 2008); *Fish'n'Steps* (Lin, et al., 2006); *UbiFit Garden* (Consolvo, et al., 2009);

*Accupedo-Pro Pedometer* (Glynn, et al., 2014); *iBurnCalories* (Khatri, 2015); *Starfish* (Paul, et al., 2017)].

These are some of the theories and theoretical models that also inform and underlie evidence-based BCTs (Michie, et al., 2008; Michie, et al., 2011; 2013; 2016). These theories are increasingly being advocated for across mHealth physical activity app literature (Michie, et al., 2009; Olander, et al., 2013; Conroy, Yang and Maher, 2014; Direito, et al., 2014; Howlett, et al., 2015; Yang, Maher and Conroy, 2015; Bardus, et al., 2016; Edwards, et al., 2016; Nuojua, 2017; Paul, et al., 2017; Samdal, et al., 2017). Yet, despite the weighty argument for the use of evidence-based BCTs, literature reviews and study analyses reveal their limited presence in mHealth physical activity apps, particularly commercial apps (Olander, et al., 2013; Conroy, Yang and Maher, 2014; Direito, et al., 2014; Yang, Maher and Conroy, 2015; Bardus, et al., 2016; Edwards, et al., 2016; Bondaronek, et al., 2018). Nevertheless, for apps that do incorporate BCTs, BCTs identified as commonly commonly associated with increased activity participation include: "self-monitoring (of behaviour and outcomes)", "goal-setting (on behaviour and outcomes)", "feedback (on behaviour and outcomes)", "reviewing (behaviour and outcome) goals", "action planning", "shaping knowledge", "demonstration of behaviour", "rewards" (social, contingent and non-specific), "prompts, cues and reminders", "social support" and "social comparison".

Behaviour Change Techniques (BCTs) are observable and identifiable in popular and/or frequently-cited, efficacious physical activity apps including: *Chick-Clique* (Toscos, et al., 2006; 2008); *Fish'n'Steps* (Lin, et al., 2006); *Houston*, *UbiFit Garden* (Consolvo, et al., 2006; 2008; 2009); *GoalPost* and *GoalLine* (Munson and Consolvo, 2012); *Everywhere Race* (Mulas, Pilloni and Carta, 2012) and *Everywhere Run* (Mulas, et al., 2013); *Pokémon GO* (Kaczmarek, et al., 2017; LeBlanc and Chaput, 2017); *Runkeeper, Strava, Sworkit, Fitocracy, Runtastic, Nike+ (Running Club* and *Training Club)* (Middelweerd, et al., 2014; Dallinga, et al., 2015; Modave, et al., 2015; Ploumen, 2016); *MapMyFitness, Endomondo, MyFitnessPal, Noom Coach, Cardio Trainer, Argus* (Khan, et al., 2012; Vaquero, 2016; Zhao, Freeman and Li, 2016); *Inspirun* (Vos, et al., 2016); *bActive* (Harries, et al., 2016; 2017); *Fitbit* (Dunn and Robertson-Wilson, 2018); *Zombies Run!, Kurbo, iBitz, NFL Play* (Direito, et al., 2015; Schoeppe, et al., 2017); *Couch-to-5K* (Direito, et al., 2014; 2015; Modave, et al., 2015; Bondaronek, et al., 2018); and *Starfish* (Paul, et al., 2017).

In reference to the most recent evidence-based BCT taxonomy v1 (Michie, et al., 2013) there are 93 possible BCTs, grouped into 16 categories. Given the limited number of techniques incorporated into physical activity apps in general, there remains considerable room for improvement and possible future knowledge contributions in terms of the number of BCTs integrated in mHealth physical activity behaviour change intervention apps, and studies addressing the design and evaluation of these various BCTs.

The underlying theories, models and constructs that inform evidence-based BCTs (located within the Health Behavioural Sciences perspective) also inform evidence-based theories, models and constructs that inform persuasive technology models, PSD principles and persuasive design strategies (Geuens, et al., 2016a; 2016b) (located within the Information Systems perspective). The same theories therefore underlie theoretical models from both perspectives.

The Persuasive Systems Design Model (PSDM) (Oinas-Kukkonen and Harjumaa, 2009) which provides 28 PSD principles has increasingly been used to inform the design of several persuasive and effective physical activity apps (Chang, Kaasinen and Kaipainen, 2012; Dominic, et al., 2013; Silveria, 2013; Al Ayubi, et al., 2014; Edwards, et al., 2014; Klein, Mogles and van Wissen, 2014; Larsson, 2015; Yoganathan and Kajanan, 2015; Geuens, et al., 2016a; Haque, et al., 2016; Lentferink, et al., 2016; Matthews, et al., 2016; Mohadis, Ali and Smeaton, 2016; Ren, et al., 2016; Boratto, et al., 2017; Haque, 2017; Kappen and Orji, 2017; Liao, et al., 2017; Qasim, et al., 2017). Some of the PSD principles frequently used in the design of effective physical activity apps include: “self-monitoring”, “tailoring”, “tunnelling”, “reduction”, “personalisation”, “praise”, “reminders”, “rewards”, “suggestions”, “liking”, “social role”, “social support”, “social comparison”, “social learning”, “social competition”, “social cooperation”, “recognition”, “normative influence” and “social facilitation” (Matthews, et al., 2016).

Upon critical overview, the overlaps between several PSD principles and BCTs becomes apparent (Geuens, et al., 2016a); such as the clearly noticeable corresponding principles and techniques for “self-monitoring”, “rewards”, “reminders” (that is, prompts and cues), “social support” and “social comparison”, to name a few. In further examining the knowledge base, a distinction between literature covering PSD principles, in comparison to literature covering BCTs, seems to relate to the *design* of the software features in physical activity apps. In other words, PSD principles are reviewed, applied and discussed in terms of *how* persuasive strategies

can be *translated* and *operationalised* into software design features. That is, technical app design features and elements that are observable and interactive through an app's user interface design. This makes sense in that persuasive technology theories and PSD models stem from the Information Systems arena, and hence view the application of PSD principles through a technological lens, thus orientating focus on the technological software design features in physical activity apps.

Some mHealth physical activity apps that have applied PSD principles include: *Chick-Clique* (Toscos, et al., 2008; Dominic, et al., 2013); *Fitness Buddy, Workout Trainer, VirtuaGym, Run Tracker Pro, JEFIT Pro, Pocket Trainer, Strava* (Yoganathan and Kajanan, 2013; 2014); *PersonA, iSmoothRun* (Al Ayubi, et al., 2014); *Runtastic, Endomondo* (Temir, 2013; Mollee, et al., 2017); *BikeTogether* (Cheng and Lee, 2015); *B-Mobile, bActive, Accupedo-Pro Pedometer* (Matthews, et al., 2016); *Fitocracy, Runkepper* (Yoganathan and Kajanan, 2013; Higgins, 2016); *Nike+ (Running Club and Training Club), Fitbit, Endomondo, MapMyFitness, FitStar, CARROT Fit, Strava (Running and Cycling), Running Plan, Running for Weight Loss* (Yoganathan and Kajanan, 2013; Bartlett, 2015; Yoganathan and Sangaralingam, 2015; Mollee, et al., 2017); *SportyPlanner* (Vaquero, 2016); *Virtual Coach, Music and Maps, Online Community* (Bartlett, Webb and Hawley, 2017); and *Pokémon GO* (Kari, Arjoranta and Salo, 2017; LeBlanc and Chaput, 2017).

As indicated above, there exists a complex, multi-dimensional, multi-faceted and intricate web of ties between these inter-connected theories, theoretical models and theoretical constructs (Harjumaa and Oinas-Kukkonen, 2007; Michie, et al., 2008; Oinas-Kukkonen and Harjumaa, 2009; Michie, et al., 2011; 2013; Simons, 2016; Funmilayo, Afolashade and Oludele, 2017). For example, Self-Efficacy Theory (Bandura, 1977; 1994) – a core construct of Social Cognitive Theory (Bandura, 1986) – originates from the field of psychology, yet is intimately tied to the field of Health Promotion (Bandura, 1998; 2004; Bartholomew Eldredge, et al., 2016), and intra-interpersonal socioecological intervention design (Glanz and Bishop, 2010; Angus, et al., 2013; Glanz, Rimer and Viswanath, 2015). Self-Efficacy Theory also underpins several behaviour change models (Holloway and Watson, 2002; Davis, et al., 2015; Atkins, et al., 2017) and evidence-based BCTs (Michie, et al., 2004; Abraham and Michie, 2008; Michie, et al., 2008; 2009; 2011; 2013; 2016). Furthermore, Self-Efficacy Theory informs a handful of persuasive technology and behaviour change support systems models (Fogg, Cuellar and Danielson, 2007; Oinas-Kukkonen, 2010; Orji, 2014; Funmilayo, Afolashade and Oludele, 2017) and PSD principles (Oinas-Kukkonen and Harjumaa, 2009). Moreover, Self-Efficacy

Theory is incorporated in technological acceptance and usability models (Martin, 2007; Ratten and Ratten, 2007; Jen, Lu and Liu, 2009; Akinbobola and Adeleke, 2013; Tsai, 2014; Al-Mamary, et al., 2016). Overall, there is paramount evidence that theories influence the final design of mHealth physical activity apps.

Challenges arise in terms of *how* BCTs and PSD principles (and hence their underlying theoretical models and constructs) are "translated" (Middelweerd, et al., 2014, p.103), "applied" (Geuens, et al., 2016b, p.e121) or "operationalised" (Geuens, et al., 2016a, p.167; Paul, et al., 2017, p.4; Perski, et al., 2016, p.254; Schoeppe, et al., 2017, p.89) as design features in physical activity apps. In other words, the *way* in which app designers/developers 'convert' these BCTs and PSD principles into design features that are observable and interactive through the apps' user interfaces, graphical displays, features and functionalities, ultimately affects the overall usability, and hence effectiveness (or effective potential) of the app-based physical activity (health promotion) behaviour change intervention. Furthermore, Dahlke, et al. (2015, p.1) explains that "many [mHealth] apps appear to deliver health [promotion] behaviour [change] interventions but fail to consider design considerations based in human computer interface and health behaviour change theories". Mobile apps, and mobile technologies in general, are thus often used as a "mere tool that has no effect or value and serves only as a vehicle for delivery of intervention content" (Kelders, et al., 2012, p.1). Intervention designers are therefore "often not aware of the subtle messages the technology in itself can convey" (Geuens, et al., 2016a, p.166).

Further complicating this challenge concerns the *way* in which these theories, BCTs and PSD principles are applied and operationalised can differ significantly across all research and mHealth physical activity consumer apps; described by Kaptein, et al. (2015, p.39) as "differing levels of exhaustiveness, exclusively, emphasis, and granularity". Geuens, et al. (2016a, p.167) also illuminates this health behaviour change app design and theory issue by explaining that BCTs and PSD principles are "often hard to operationalise ... as they [are] often described at the level of individual judgement". This denotes that BCTs and PSD principles are generally operationalised in accordance with app designers'/developers' various, and often diverse, subjective interpretations of the BCTs' and PSD principles' terminological (and theoretical) interpretations and meanings. The differing operationalised application of BCTs and PSD principles as design features in physical activity apps can be further clarified by an example.

For instance, “rewards”, is a shared BCT and PSD principle (and a popular gamification strategy (Berkovsky, et al., 2010; Fanfarelli, Vie and McDaniel, 2015; Richter, Raban and Rafaeli, 2015)) frequently used in the design of effective mHealth physical activity apps. In the *Starfish* physical activity app (Paul, et al., 2017, p.2), upon reaching the daily 10 000 step-count target goal for at least five days of a week, users receive a “reward” operationalised through the provision of an additional “sea creature”, represented as a crab or an octopus in their app’s on-screen fish tank. The *CARROT Fit* physical activity app offers “rewards” to users through the provision of “credit points” (Larsson, 2015, p.20). The *UbiFit Garden* app (Consolvo, et al., 2008; Munson and Consolvo, 2012) generates a glanceable image display of a garden on the user’s smartphone wallpaper interface, and offers “rewards” in the form of a virtual “flower” for each activity performed and a “butterfly” upon goal attainment. Other physical activity apps operationalise “rewards” offered through points and bonus points [*NEAT’O’GAMES* (Fujiki, et al., 2008) and *PLAY, MATE!* (Berkovsky, et al., 2010)], virtual markets and virtual currency [*Move2Play* (Bielik, et al., 2012)], and through ribbons and trophies [*GoalPost* and *GoalLine* (Munson and Consolvo, 2012)]. In Vaquero’s (2016, p.38) *SportyPlanner* physical activity app, “rewards” are operationalised in the form of virtual “badges” which can accumulate and be converted into real-life “discount vouchers” for users to use when purchasing items from online sport stores. Other physical activity apps *Fitbit* (Munson and Consolvo, 2012), *StepStream* (Miller, 2014) and *MAPS* (Fanning, 2016) also “reward” users with virtual “badges”.

The shared BCT and PSD principle “rewards” is itself multi-dimensional and can be broken down further as it can pertain to either extrinsic or intrinsic rewards (Fanfarelli, Vie and McDaniel, 2015; Richter, Raban and Rafaeli, 2015), and can be operationalised into various forms or types, such as “virtual or digital rewards”, “tangible rewards”, “intangible rewards”, “non-materialistic rewards”, “materialistic rewards”, “non-specific rewards”, “social rewards”, “self-rewards”, and “financial rewards” (Michie, et al., 2013; Lister, et al., 2014; Fanning, 2016; Peng, et al., 2016). Several studies have also revealed the different subjective perceptions, views, opinions and (hedonic) emotions experienced by different users, in response to varying applications of the operationalised “rewards” technique and principle (Peng, et al., 2016). For instance, some users respond positively to receiving real-life “materialistic” rewards such as money and discount vouchers, while others respond better to “virtual” rewards such as badges and trophies, or “verbal” rewards (Middelweerd, et al., 2015; Fanning, 2016; Peng, et al., 2016).

Studies investigating users’ perceptions, views, opinions and emotional experiences of BCTs (Murnane, Huffaker and Kossinets, 2015; Schoeppe, et al., 2017), mechanisms of action (Hoj,

et al., 2017), PSD principles (Lehto, 2013; Peng, et al., 2016; Halttu and Oinas-Kukkonen, 2017) and app design features (Stroulia, et al., 2013; Middelweerd, et al., 2015; Mollee, et al., 2017) have increased. The main reason increase is the rising realisation for the relevance and significance of the inter-connected ties between users' positive experiences in relation to their intrapersonal dynamics (for example, self-efficacy and outcome expectations) and motivation (towards physical activity participation). These positive experiences are also tied to the users' continued app engagement and usage, and their belief, attitudinal and behavioural changes, as well as their overall acceptance, adoption and adherence to both the physical activity intervention and app (Middelweerd, et al., 2015; Yoganathan and Sangaralingam, 2015; Wang, et al., 2016; Mollee, et al., 2017; Schoeppe, et al., 2017).

Another issue concerning the identification, application and operationalisation of these BCTs and PSD principles (and their underlying theories and constructs) in physical activity apps relates to their "ambiguous" descriptions (Geuens, et al., 2016a). To explain, on the one hand, a specific BCT or PSD principle can be operationalised into a particular app design feature. However, on the other hand, the presence and identification of a particular app design feature does not necessarily imply it is informed by a specific BCT or PSD principle. "Rewards" (a BCT and PSD principle), for instance, can be operationalised as a "virtual badge" (design feature), however, the presence of a "virtual badge" (design feature) can be informed by "rewards", "feedback on behaviour", "feedback on performance", "feedback on outcomes", or "narrative-based and story-orientated metaphors" (Fanfarelli, Vie and McDaniel, 2015). In response to this issue, Geuens, et al. (2016a, p.167) suggests app designers provide "rationales for [their] design choices" and "to hypothesise how design choices in health apps are likely to motivate and effect" behaviour change.

These challenges highlight the need for more explicit reporting of the translation and operationalisation of BCTs and PSD principles by app designers, researchers and practitioners, as well as the need for standardised and detailed patterns to guide the operationalisation of techniques and principles into app design features. The Behaviour Change Support Systems' (BCSS) "reward design pattern" (Alahaivala, Odour and Oinas-Kukkonen, 2014) and "social influence design pattern" (Odour, Alahaivala and Oinas-Kukkonen, 2014) are examples of detailed descriptions and guidelines proposed to inform and assist app designers and developers in the technical operationalisation of techniques and principles as software design features. Overall, in essence, there exist several multi-faceted challenges and issues concerning the application and operationalisation of BCTs and PSD principles into mHealth physical activity

app design features. All of this impacts users' perceptions, views and experiences with the apps, and ultimately affects users' acceptance, adoption, continued usage (and engagement) and adherence to both the app and the intervention delivered through the app.

A variety of development approaches, processes and methods have been applied by researchers, practitioners and app designers in the development of effective physical activity apps. The human-centred design and user-centred design approaches were adopted for informing the design, development and evaluation of physical activity apps including *It's LiFe!* (van der Weegen, et al., 2013); *Social Sport* (Weng, et al., 2013), *Back on Bike (BoB)* cycling app (Geurts, et al., 2016); *BeWell24* (Buman, et al., 2016); *MAPS* (Fanning, 2016); *SportyPlanner* (Vaquero, 2016); *Inspirun* (Vos, et al., 2016); and *GetHealth* (Haque, 2017). Usability and user experience design evaluation testing methods (stemming from the Information Systems perspective) are often used in gathering and analysing users' perceptions, opinions and feedback on the effectiveness, efficacy, usability, usefulness, ease of use, user interface and overall design of physical activity apps. Examples of physical activity apps which have been evaluated in terms of usability and user experience design include: *Chick-Clique* (Toscos, et al., 2006; 2008)*; Houston*, *UbiFit Garden* (Consolvo, et al., 2006; 2008; 2009); *NEAT'O'GAMES* (Fujiki, et al., 2008); *GoalPost* and *GoalLine* (Munson and Consolvo, 2012); *iStepLog* (Kirwan, et al., 2012); *Everywhere Race* (Mulas, Pilloni and Carta, 2012); *Everywhere Run* (Mulas, et al., 2013); *It's LiFe!* (van der Weegen, et al., 2013); *Back on Bike (BoB)* (Geurts, et al., 2016); *iGo* (Haque, et al., 2016); *FitSenior* (Mohadis, et al., 2016); *SportyPlanner* (Vaquero, 2016); *Twazon* (Alnasser, et al., 2016); *Inspirun* (Vos, et al., 2016); *GetHealth* (Haque, 2017); and *Starfish* (Paul, et al., 2017).

Rapid and iterative prototyping design-test-refine cycles as advocated for by several approaches (covered in the thesis's main body discussion in Section 4.4) have been used to inform the design, development and evaluation of mHealth physical activity apps. There are a handful of approaches (Kushniruk, 2002; Whittaker, et al., 2012; Kisner, 2013; Becker, et al., 2014; Bradbury, et al., 2014; Johnston, et al., 2015; Mummah, et al., 2016; Nguyen and Poo, 2016; Smith, et al., 2016; Yardley, et al., 2016a; Wang, et al., 2017). These approaches have been used to inform the iterative design and prototyping of several physical activity apps, such as: *Back on Bike (BoB)* (Geurts, et al., 2016); *BeWell24* (Buman, et al., 2016); *iGo* (Haque, et al., 2016); *Inspirun* (Vos, et al., 2016); and *SportyPlanner* (Vaquero, 2016). Various other approaches have been used to inform the design of mHealth physical activity behaviour change intervention apps. The *POWeR Tracker* app used a mixed-method study design (Morrison, et

al., 2014). The *Inspirun* app (Vos, et al., 2016) used a collaborative multi-disciplinary and three-step (profiling, designing and validating) mixed (combination of qualitative, quantitative and design strategy) methods approach. The *iStepLog* app was evaluated using other theoretical frameworks such as the Information Systems' Technology Acceptance Model (TAM) (Kirwan, et al., 2012).

The integration of gamification theories, models and strategies, and game design elements are increasingly gaining popularity in the design of effective physical activity apps (Fujiki, et al., 2008; Berkovsky, et al., 2010; Lister, et al., 2014; Payne, et al., 2015b; Edwards, et al., 2016; Edney, et al., 2017; Kaczmarek, et al., 2017; LeBlanc and Chaput, 2017; Pope, Garnett and Dibble, 2017; van Dyck, 2017; Kappen, Mirza-Babaei and Nacke, 2018). Gamification theory and gaming strategies (operationalised as app design features and functionalities) have proven to be associated with motivation (Schell, 2008; Alahaivala and Oinas-Kukkonen, 2016; Wong and Kwok, 2016; van Dyck, 2017; Kappen, Mirza-Babaei and Nacke, 2018). They have also shown to be positively associated with desires to compete, socialise, embark on adventures (such as journeys, quests and challenges), pursuit and achieve (goals), and to play and participate in fun and enjoyable experiences (Schell, 2008; Payne, et al., 2015b; Wong and Kwok, 2016; van Dyck, 2017; Kappen, Mirza-Babaei and Nacke, 2018).

Gamification has been linked to BCTs (Edwards, et al., 2016; Kaczmarek, et al., 2017), PSD principles (Alahaivala and Oinas-Kukkonen, 2016; Kappen and Orji, 2017; Kari, Arjoranta and Salo, 2017; Kappen, Mirza-Babaei and Nacke, 2018), and physical activity app design features (Edwards, et al., 2016; Wong and Kwok, 2016; Edney, et al., 2017; Pope, Garnett and Dibble, 2017; van Dyck, 2017). mHealth physical activity apps that have proven to demonstrate effectiveness owing to the incorporation of gamification include: *NEAT'O'GAMES* (Fujiki, et al., 2008); *BunnyBolt* (Keung, et al., 2013); *BikeTogether* (Chen and Lee, 2015); *Yoga Retreat, iBellyWorkout, Walk It!, The Walk, RunAlice, Ninja Fitness, NFL Play, StreetQuest, Habit Monster, FitQuest, 7 Minute Workout, Walkr, Hike the World, Runno* (Payne, et al., 2015b); *FitPet* (Tong, et al., 2015); *Zombies Run!* (Direito, et al., 2015; Payne, et al., 2015b); *CityU Walk* (Wong and Kwok, 2016); *Active Team* (Edney, et al., 2017); *Pokémon GO* (Kaczmarek, et al., 2017; Kari, Arjoranta and Salo, 2017; LeBlanc and Chaput, 2017); and *Spirit50* (Kappen, Mirza-Babaei and Nacke, 2018).

Randomised controlled trials (RCTs) and experimental study methods (also identified in the thesis's Section 4.4) have been used to evaluate the effectiveness of mHealth physical activity

apps (Whittaker, et al., 2012; Bradbury, et al., 2014; Mohr, et al., 2014; Johnston, et al., 2015; Jacobs and Graham, 2016; Mummah, et al., 2016; Murray, et al., 2016; Smith, et al., 2016). Examples of these apps include: *Balanced* (Duncan, et al., 2016); *BeWell* (Lane, et al., 2011); *Lose It!* (Allen, et al., 2013); *Accupedo=Pro Pedometer* (Walsh, et al., 2016); *bActive* (Harries, 2016; Harries, et al., 2017); *ActiveTeam* (Edney, et al., 2017); *AFIT* (Watterson, et al., 2017); *EVIDENT 2* (Recio-Rodriguez, et al., 2016; Gomez-Marcos, et al., 2018); and *EVIDENT 3* (Recio-Rodriguez, et al., 2018).

Other tools are also frequently used to test and evaluate mHealth physical activity behaviour change intervention apps. For instance, Mobile App Rating Scale (MARS) (Stoyanov, et al., 2015) is quickly becoming a well-recognised, reliable and useful measurement tool for reviewing and evaluating the quality of both research-driven and commercial physical activity consumer apps (Patel, 2015; Anderson, Burford and Emmerton, 2016; Bardus, et al., 2016; Vos, et al., 2016; Schoeppe, et al., 2017). Some apps reviewed using the MARS scale include *MyFitnessPal*, *NexTrack*, *Pacer*, *Lark*, *MSN Health & Fitness*, and *My Diet Coach Pro* (Bardus, et al., 2016); *Inspirun* (Vos, et al., 2016); as well as *Fitbit, Sworkit, Zombies Run!, Walkr, NFL Play, Pokémon GO, Kurbo, Runbit, Ninja Fitness, Dungeon Runner, iBitz, and Kid's Fitness* (Schoeppe, et al., 2017). In brief, the MARS scale allows app designers, developers, evaluators and researchers to evaluate apps across 19 items, grouped into four domains: (1) engagement (entertainment, interest, customisation, interactivity, target group); (2) functionality (performance, ease of use, navigation, gestural design); (3) aesthetics (layout, graphics, visual appeal); and (4) information quality (accuracy of app description, goals, quality and quantity of information, visual information, credibility, evidence base) (Stoyanov, et al., 2015). All 19 items are measured on a 5-point rating scale (1 = inadequate to 5 = excellent), after which a score for each domain is calculated, and the overall MARS score is computed as an average across all four domains (Stoyanov, et al., 2015).

On another note, several multi- and inter-disciplinary approaches have been employed by collaborating teams who worked together to design, develop and evaluate physical activity apps. Some of these apps include: *PersonA* (Al Ayubi, et al., 2014); *Back on Bike (BoB)* (Geurts, et al., 2016); *BeWell24* (Buman, et al., 2016); *SportyPlanner* (Vaquero, 2016); *Inspirun* (Vos, et al., 2016); *Starfish* (Paul, et al., 2017), as well as other vendor and consumer market leading apps *Runtastic*, *Fitbit*, *MyFitnessPal*, *Endomondo*, *Strava*, *Noom*, *Couch-to-5K*, *MapMyFitness*, and *Pokémon GO*.

The multi- and inter-disciplinary teams involved experts from varying fields with specialist knowledge relevant to the design, development and evaluation of physical activity apps, including: health experts (such as experts in medicine, physical activity, weight loss/management, sedentary behaviour, dietetics and nutrition, personal training and exercise); medical professionals (such as doctors and nurses); psychologists; mHealth app designers and software engineers; behavioural change specialists; persuasive technology and persuasive systems designers; game designers and developers; potential target users (end user representatives); and other stakeholders (Alnasser, et al., 2016; Buman, et al., 2016; Vaquero, 2016; Vos, et al., 2016; Paul, et al., 2017).

Multi- and inter-disciplinary teamwork, and the sharing of expert knowledge and skills, is significantly valuable and necessary for the design of effective physical activity apps (Klasnja and Pratt, 2012; Millington, 2014; Helf and Hlavacs, 2016; Knittle, et al., 2016; Cameron, Ramaprasad and Syn, 2017; Jee, 2017; Kao and Liebovitz, 2017; Michie, et al., 2017; Wang, et al., 2017). However, many concerns exist regarding the timeframes and resources required for ensuring that teams are properly established, guided and facilitated in the executing of various tasks throughout an app's development process, and that all collaborative interactions and tasks are of a high quality. Ensuring high quality processes means that reliable and evidence-based methods are used, reporting standards are adhered to, and that the details of processes and methods are documented and published for dissemination (to grow the knowledge base). The *Twazon* app (Alnasser, et al., 2016), for instance, was developed using a multi-disciplinary team, but took 23 months to execute the collaborative design, development and evaluation tasks. In the rapidly growing and changing mHealth app environment, a 23-month multi- and inter-disciplinary development process is infeasible. Similarly, while Vos, et al.'s (2016) study demonstrated strengths in its multi-disciplinary team and cyclical design-test-refine iterative approach to app development (including a total of three design and evaluation cycles), the study was reported to have started in winter 2014 (Northern Hemisphere) and was only planning to conduct a large scale quantitative trial by spring 2016.

There are many other publications available in the current knowledge base, especially given the time lapse from when this critical review was initially conducted in early 2018 to present date in 2021. Nevertheless, these publications and findings reveal valuable findings pertaining to design challenges and the effectiveness of mHealth intervention apps, and apps specifically targeting the promotion of physical activity behaviour change.

# Appendix E (Chapter 4): Persuasive Technology and Persuasive Systems Design

## 4.4.2 Design Related Challenges in Consumer mHealth Behaviour Change Intervention Apps: Persuasive Technology and Persuasive Systems Design

Persuasive systems design (PSD) principles, informed by the Persuasive Systems Design Model (PSDM) (Oinas-Kukkonen and Harjumaa, 2009) which falls within the fields of persuasive technology and health behaviour change support systems, refer to specific strategies that intend to ethically persuade, influence and change humans' attitudes and behaviours towards a particular modifiable health behaviour (Sporrel, et al., 2021). Appendix E provides a broader discussion on the fields of fields of persuasive technology and persuasive systems design, to demonstrate the researcher's understanding of these areas of study. These two fields of study are not the sole focus in this research and hence are excluded from the main body thesis discussion and extracted into this appendix.

*"Persuasion has always been part of the human experience… and like the human persuaders in our lives persuasive computing technologies can bring about constructive [behavioural and attitudinal] changes in many domains, including health."*
*– Fogg (1999) –*



### 4.4.2.1 Persuasive Technology

*Persuasive technology* is broadly defined as technology that is designed to change attitudes and behaviours of the users through persuasive and social influence strategies (Fogg, 2002). This does not necessarily include coercion, and more specifically, ethical persuasive technology advocates against the use of coercive tactics (Fogg, 2003). In order to change individuals' attitudes and behaviours towards their own health and wellbeing, and particularly their physical activity behaviour, it is necessary that the individuals' hold attitudes and engage in behaviours that are aligned with the desired health behavioural change outcomes.

The study of persuasion can be dated back to the classical Greece era over 2,300 years ago, when Artistotle was a leading thinker on *rhetoric* – "the art of determining how to persuade in

any given situation" (Fogg, 2003). Historically, persuasion was studied and used by privileged Greek males when giving public speeches with the intention to influence and change listeners' moods and opinions, or motivate them to take action. Decades later, in the mid-1930s, Dale Carnegie fist published a best-selling book *How to Win Friends and Influence People*, which had a substantial impact on the subsequent popularisation of persuasive studies (Fogg, 2003). Although a there is a somewhat lack of a consensus definition for persuasion in academic communities (Fogg, 2003), Simons (1976, p.21) broadly defines *persuasion*, in general, as "human communication that is designed to influence others by modifying their beliefs, values or attitudes". Traditionally applied to politics, economics, marketing communications, propaganda and war, the design and utilisation of persuasive strategies and messages intended to persuade individuals' attitudes and behaviours has over time ripened into a well-recognised art (Simons, 1976; Fogg, 2003). Over decades, this powerful construct has become increasingly more engrained in what has become perceived as 'normal' societal functioning (Dainton, 2004) and has been extended, adapted and applied to a broad variety of contexts such as health behaviour change interventions. In the context of physical activity, persuasion can, for example, be observed in a series of interactions between two individuals, whereby one person intentionally attempts to influence and encourage another person to join them for a run or walk.

In the last two and a half decades, persuasion has filtrated into the technological arena, gaining growing popularity worldwide in all spheres of ubiquitous and digital advancements. This movement was chiefly initiated by one of founding fathers of *persuasive technology*, B.J. Fogg (1998; 1998; 2002), who after years of acquired knowledge and expertise on propaganda and persuasive communication, began exploring the relationships and parallels between the persuasive influence of technology and human users (Fogg, 1998; Fogg, 2003). In the meantime, advancements and research were also being conducted in the fields of Human Computer Interaction (HCI) and Health Promotion (such as healthy eating and physical activity), verging on the periphery of technology-based persuasive design (Fogg, 1997; 2003). Health promotion systems intended to persuade and change what individuals think and do first appeared in the 1970s and 1980s (Fogg, 2003). Thereafter, in the 1990s, the explosive emergence of the internet led to the proliferation of websites designed intentionally to persuade individuals to change their attitudes and behaviours (Fogg, 2003). For example, Amazon.com, which persuades people to purchase products, and further offers suggestions and compelling promotions based on the person's search patterns and personal preferences.

In more recent years, advancements in digital devices and apps has "exploded… and is said to be growing faster than that of any consumer technology in history" (Dipietro, 2014, p.6). This widespread adoption in combination with the accessibility and portability of mobile and tablet devices argues for the use of apps as demonstrating significant potential for delivering persuasive health promotion behaviour change interventions (Dipietro, 2014). Additionally, the emerging ambient of persuasive technology appears "very promising" for ubiquitous personal technologies ranging from smartphone and tablet apps to personal digital assistants, websites and other pervasive computing systems (Oinas-Kukkonen, 2013, p.1223). The power associated with the design of personal persuasive platforms, such as mHealth physical activity behaviour change intervention apps, have gained amplified recognition (Oinas-Kukkonen and Harjumaa, 2008; Al Ayubi, et al., 2014; Bartlett, 2014; Orji, 2014; Larsson, 2015; Kasali, et al., 2017; Wang, et al., 2018; Amutari and Orji, 2019; Haque, 2020; Sporrel, et al., 2021).

Based on exploratory studies and investigations, Fogg (1997) identified a literary gap focusing on the study of computers as persuasive technologies, leading him to coin the term *Captology.* Captology relates to the overlap between technology and persuasion (Figure Appendix E.1) and is an acronym for the study of *computers as persuasive technologies*; described as a *"focus on the design, research and analysis of interactive computing products [i.e. systems or applications] created for the purpose of changing people's attitudes and behaviours"* (Fogg, 1997; 2003, p.5). Simply defined, Captology described the study of "computers as persuasive technologies" (Fogg, 1997, p.129). Furthermore, in the context of persuasive technologies, Fogg (2003, p.15) defines *persuasion* as "an attempt to change attitudes or behaviours or both without using coercion or deception". *Persuasive systems*, according to Oinas-Kukkonen and Harjumaa (2008) can be described as computerised software or information systems designed to reinforce (reinforce existing), change (change person's response(s)) or shape (form new pattern) attitudes or behaviours or both without coercion or deception.

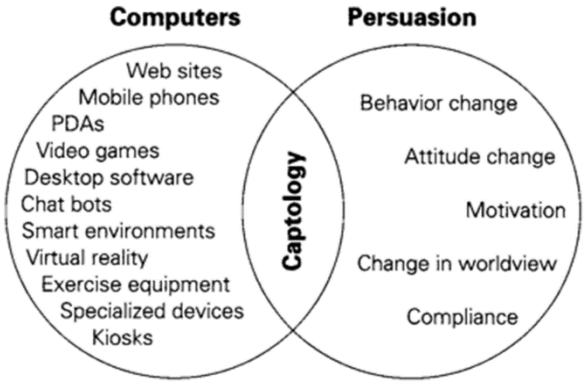



*Figure Appendix E.1: Captology (Persuasive Technology) [Source: Fogg (1997)]*

The distinction between traditional human-orientated persuasion and persuasive technology lies in the element of *interactivity*, whereby, based on the user's interactions with the apps, an app (as the persuader) is able to effectively adapt its persuasive influence tactics in accordance with a user's needs, goals and situational context (Fogg, 2003). These interactions are realised through the app's incorporation of persuasive design principles and subtle messages communicated to users, intentionally aimed at persuading individuals to take control over the decisions affecting their health and well-being (Haque, 2020).

Notably, as also implied and mentioned, there is a distinction between *persuasion* and *coercion*, with the former implying a voluntary change in attitude and/or behaviour, and the latter implying a forced change in attitude and/or behaviour (Fogg, 2003; 2007; Karppinen and Oinas-Kukkonen, 2013). Similarly, there is a difference between *persuasion* and *deception* in that deception makes studious use of false reporting and misinformation as a means of influencing individuals (Fogg, 2003; 2007; Karppinen and Oinas-Kukkonen, 2013). Given the neglect for an individual's voluntary willingness and desire to change his/her behaviour, both coercion and deception are deemed unethical in the practice of persuasive technology and therefore unacceptable in the design of ethical persuasive mHealth (promotion) behaviour change intervention apps (Fogg, 2003; 2007; Karppinen and Oinas-Kukkonen, 2013). In other words, persuasive effects should be endogenous, meaning they should be intentionally embedded in an app's design, and should bring about intended persuasive effects, rather than unintended side effects or outcomes (Karppinen and Oinas-Kukkonen, 2013). This concept of *intentionality* distinguishes the potential harmful effects of persuasive technologies and the planned effects, and in the context of this research is concerned with intended and ethical persuasive effects and outcomes (Karppinen and Oinas-Kukkonen, 2013). This further requires an element of *predictability* (Karppinen and Oinas-Kukkonen, 2013), whereby the persuasive effects resulting from the incorporation and representation of persuasive design principles (strategies) is somewhat predictable and has through empirical studies, demonstrated positive effects on individuals' motivation and actions towards physical activity behaviour change.

Persuasive technology and persuasive systems design plays an important theoretical and practical role in the design of effective mHealth (physical activity) behaviour change intervention apps. The design and operationalisation of persuasive design principles may however vary depending on the mode through which persuasive behavioural interventions are delivered, for example, apps versus desktop websites. Amongst other factors, the health behaviour domain (physical activity, healthy eating, smoking cessation, depression, sleep, et

cetera), target audience-relevant demographics (children, adults, older adults, gender, chronic health conditions) and other environmental elements (cultural norms) will also influence the way persuasive strategies are translated into software design features (Orji, 2014; Haque, 2020). Health status, income and educational levels, and factors specific to the digital platform as also affect the potential persuasive influence of an intervention (Free, 2013).

Generally, the knowledge base on persuasive technology, persuasive systems and persuasive design remains ongoing, yet over recent years, has been growing in popularity. Despite the consideration that the study of persuasion extends back over 2,300 years, a deep understanding of persuasion remains limited (Fogg, Cuellar and Danielson, 2009). The main reasons for this is due to the complexity of human psychological and sociological behavior, the extensive breadth and depth of the persuasive domain as a whole, the fuzzy boundaries delineating the various digital platforms, and ongoing rapid advancements in technology (Fogg, Cuellar and Danielson, 2009). If persuasion strategies were better understood, the integration and design of interactive persuasive technologies and persuasive mHealth behaviour change apps would be far easier than it currently is. Moreover, there is no universal theory or framework for comprehensively describing persuasion and persuasive technology/systems in their entirety, and therefore it becomes necessary to draw from various theories, frameworks and models when intending to design persuasive mHealth behaviour change intervention apps. As a result, frameworks and models have been developed particularly suited to interactive technologies and various domain context, such as physical activity (ref) or carbon omissions (ref). Furthermore, because of the characteristics specific to the design of interactive technologies such as mobile and tablet apps, new persuasion frameworks are required to enhance the knowledge base.

#### 4.4.2.2 Persuasive Technology and Persuasive Systems Design: Theoretical Frameworks and Models

This subsection discusses a few key theoretical frameworks and models in persuasive technology and persuasive systems design, including: The Functional Triad (Fogg, 2003); The Fogg Behavioural Model (FBM) (Fogg, 2009); and The Persuasive Systems Design Model (PSDM) (Oinas-Kukkonen and Harjumaa, 2009).

##### 4.4.2.2.1 The Functional Triad

The functional triad is a conceptual framework (Figure Appendix F.2) that highlights the potential roles for persuasive technologies in persuading and changing individuals' attitudes

and behaviours (Fogg, 2003). In other words, it is a framework for analysing and designing interactive persuasive technologies, by identifying three possible roles that can be played from the perspective of the user interacting with the technology (tool, medium or social actor) (Fogg, 2003). The following discussion explains how mHealth physical activity behaviour change intervention apps can play each of the three roles.

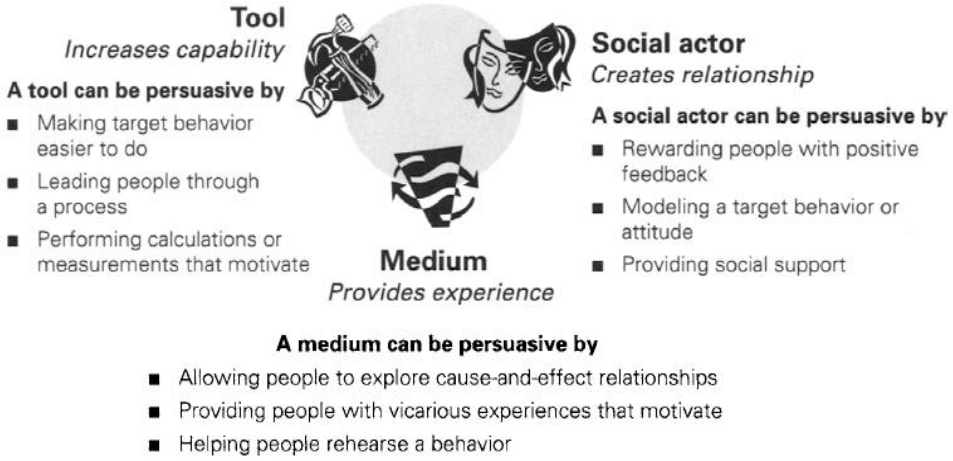



*Figure Appendix E.2: The Functional Triad: Technologies can Persuade in Different Ways, Depending on their Functional Role [Source: Fogg (2003)]*

Firstly, as a *tool*, mHealth physical activity behaviour change intervention apps can persuade individuals in a number of ways. Some examples are by: making a target behavior or activity easier to perform; leading people through an activity or process step-by-step; or performing calculations or measurements that motivate people towards physical activity participation (such as recording a person's daily steps for them) (Fogg, 2003). Although there are various ways to design mHealth physical activity apps to embody the role of a persuasive tool, Fogg (2003) and Fogg, Cuellar and Danielson (2009) offer several empirically-based ways of doing this. These are by: increasing self-efficacy; providing tailored and customised information (through the provision of suggestions, self-monitoring and tracking, and through behavior reinforcement); triggering positively influential decision-making; and simplifying and guiding individuals through their physical activities and overall progress (Fogg, 2003; Fogg, Cuellar and Danielson, 2009). These strategies correspond to BCTs and PSD principles discussed in the thesis's main body discussion in Section 4.4.

Secondly, as a *medium*, the aim would be to design mHealth physical activity behaviour change intervention apps that enable understanding through observed experiences. This is achieved by:

allowing individuals to explore cause-effect relationships (such as showing the potential side effects of exercise on weight); providing first-hand, vicarious and/or sensory experiences that motivates individuals (such as virtual worlds and simulations); or helping support individuals when rehearsing particular behaviours and activities (such as rehearsing) (Fogg, 1999; Fogg, 2003). Moreover, as a medium (also referred to media), the design-related translation and operationalisation of persuasive design principles (strategies) through the user interface of mHealth physical activity apps can either be expressed through symbolic objects (such as icons, imagery, text) or sensory content (such as simulations and virtual worlds mentioned above) (Fogg, Cuellar and Danielson, 2009).

Thirdly, as a *social actor*, the embodied role of mHealth physical activity behaviour change intervention apps would be to persuade individuals by creating a 'personal' relationship with the user (Fogg, 2003). Empirical research has proven individuals to display social, reciprocal relationships with interactive technologies like mobile smartphone devices, and to demonstrate emotional responses to their personal smartphone devices (Fogg and Nass, 1997; Vincent, 2006 Thorsteinsson and Page, 2015). Social and emotional responses can be invoked in users by designing the presentation of apps to embody animated characters (such as virtual coaches or virtual opponents/competitors) and animated characteristics (by personifying the voices, emotions and physical features of characters) (Vincent, 2006; Thorsteinsson and Page, 2015). Designing an app to demonstrate social dynamics, such as welcoming and praising users, is another way to cultivate a reciprocal relationship with a user (Fogg, 1999; 2003). Additionally, mHealth physical activity apps can also play the role of social actors, through the provision of socially support, the leveraging of social rules and dynamics (such as politeness, praise and reciprocity), and can also model specific behaviours or physical activities which the user can grasp through observational learning (Fogg, 2003; Fogg, Cuellar and Danielson, 2009).

When designing mHealth physical activity behaviour change intervention apps, more than one role can be employed, thus optimising their persuasive potential to change individuals' attitudes and behaviours regarding physical activity. Oinas-Kukkonen and Harjumaa (2007; 2009), argue that while the functional triad is useful for informing the general design and evaluation of interactive persuasive technologies, it is too limited to be applied directly to persuasive systems design, development and evaluation. In other words, a weakness of the model is that it does not explain how the suggested persuasive design principles (strategies) can and should be translated and operationalised into software requirements, such as app user interface design features and

elements. Their attempt to address this weakness is presented in their Persuasive Systems Design Model (PSDM) – discussed in this Subsection 4.4.2.2.3 below.

#### 4.4.2.2.2 The Fogg Behavioural Model (FBM)

A few years after the publication of the functional triad, Fogg (2009) proposed the Fogg Behaviour Model (FBM) as a model for describing, understanding and somewhat predicting human behavior. In this model (Figure Appendix F.3), a targeted behaviour (denoted by the star) is illustrated as a product of the relationship between three principle factors. These three factors are (1) an individual's motivation, (2) an individual's ability to perform a behaviour (simplicity), and (3) the triggers prompting a particular action or behavior in an individual (Fogg, 2009). Subcomponents of the FBM are also provided (Fogg, 2009). Figure Appendix F.4 provides examples of these subcomponents. In short, the FBM asserts "that for a target behaviour to happen, a person must have sufficient *motivation*, sufficient *ability*, and an effective *trigger*", and that "all three factors must be present at the same instant for the behaviour to occur" (Fogg, 2009, p.1).

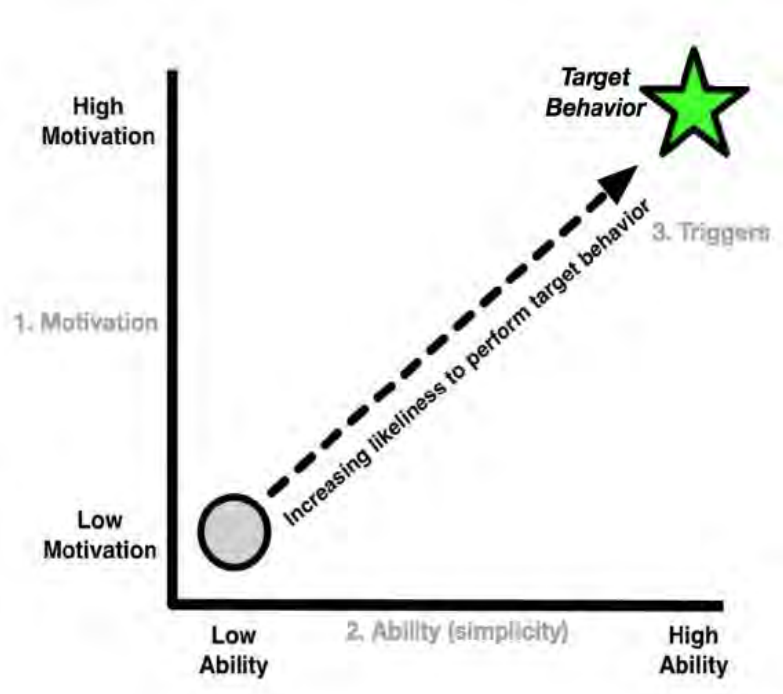



*Figure Appendix E.3: The Fogg Behavioural Model (FBM) [Source: Fogg (2009)]*

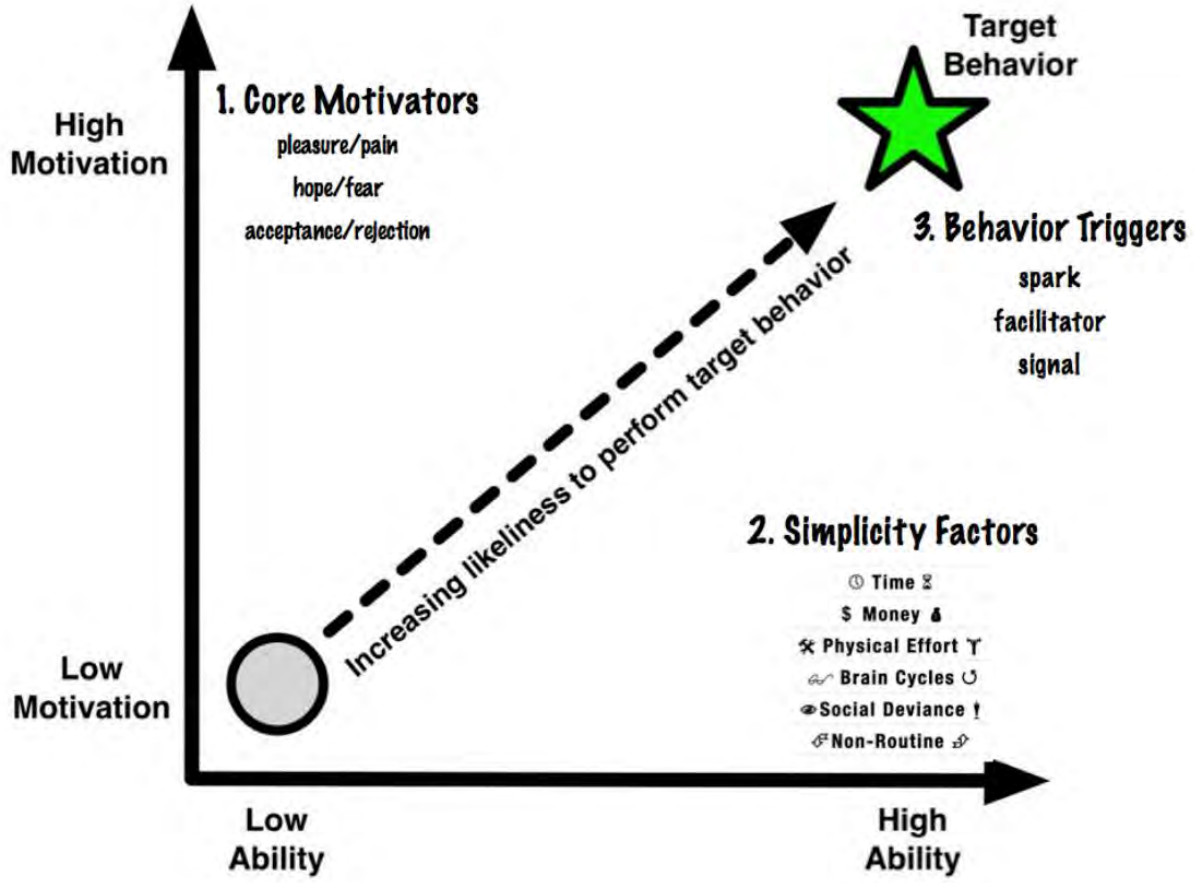



*Figure Appendix E.4: Examples of Subcomponents in The Fogg Behavioural Model (FBM) [Source: Fogg (2009)]*

*Motivation* is a theoretical construct used to describe the needs and desires that cause an individual to behave in a particular way, and what prompts them to want to repeat or not repeat a specific behaviour or activity (Ryan and Deci, 2000; Fogg, 2009). The FBM has three core motivators, each with two dichotomies, which can be incorporated and translated into an app's (user interface) design features to boost individuals' motivation levels (Fogg, 2009). The three core motivators span: (1) a pleasure versus pain dimension, (2) a hope versus fear dimension, and (3) a social acceptance versus social rejection dimension.

Although motivation is a powerful key theory in persuasion and health behaviour change, the FBM clearly claims that motivation alone, regardless of how high, may not necessarily result in actual behavior change in individuals if their *ability* to perform an activity is hindered in any way (Fogg, 2009). In addition, both motivation and ability need to be at a non-zero level for a particular behaviour to be triggered effectively (Fogg, 2009). Contrary to popular belief, individuals do not respond positively to teaching- or educational-based approaches to increase

ability since it requires them to make an active effort to learn. Ability can rather be indirectly increased if persuasive designers create for positive user experiences that enhance the efficiency of carrying out and completing a specific task or activity. *Ability*, therefore, relies heavily on the power of *simplicity*, which persuasive designers can use to reduce barriers for individuals to more efficiently perform particular tasks or activities (Fogg, 2009). Designing mHealth physical activity behaviour change intervention apps that provide for more simple and efficient interactions requires consideration of six related and interlinked parts, namely: time, money, physical effort, brain cycles, social deviance, and non-routine (Fogg, 2009).

Although *motivation* and *ability (simplicity)* are both important to persuading behavior change, the relationship between motivation and ability can also exhibit an inverse relationship (Fogg, 2009). For example, a person might have the ability to run 5 kilometers in 40 minutes, but may lack the motivation necessary to actually perform the run. Alternatively, a person might feel highly motivated to run 5 kilometers, but perhaps has an ankle injury that prohibits their ability to actually perform the run.

*Triggers* are equally important to consider along with *motivation* and *ability*, as well as how to design and communicate triggers effectively through apps. Tiggers are important because even in the event that an individual's motivation and ability towards physical activity is high, it is not definitive that they will perform a particular activity. Frequently, without a trigger, target behaviours (such as physical activity exercises or workouts) may not necessarily occur (Fogg, 2009). Fogg (2009) identifies three types of trigger, which do not function in the same way. These triggers include: a spark trigger (aims to motivate behaviour; in response to a lack of motivation); a facilitator trigger (aims to make a behaviour easier; in response to high motivation and low ability); and a signal trigger (aims to indicate or remind a user about something; when motivation and ability are present) (Fogg, 2009). Additionally, effective triggers generally have three characteristics: (1) they need to be noticed by a user; (2) they need to be associated with the intended behaviour or a specific task/activity; and (3) they need to occur when the app user is both motivated and able to perform the given task/activity or behaviour (Fogg, 2009). The latter characteristic relates to the principle of *Kairos* – described at the "opportune moment to persuade" (Fogg, 2009, p.3). Although not depicted in the FBM Figure Appendix F.4, Fogg (2009, p.3) describes the concept of a "behaviour threshold", whereby if an individual (who is motivated and able) is placed above or below this threshold, the trigger will prompt them to perform or not perform a behaviour or task/activity, respectively. In terms of designing triggers, a well-timed cue is likely to receive a favourable response;

however, if an individual lacks either the motivation or the ability to perform a particular task/activity or behaviour, their emotions can be negatively affected, evoking feelings of frustration and discouragement.

The FBM is valuable for informing the design of effective and persuasive mHealth physical activity behaviour change intervention apps; it provides insight into understanding that, in order to change an individual's physical activity behaviour, the apps need to be designed in ways that simultaneously balance the individual's motivation(s), ability(ies) and trigger(s). The concept of triggers is apparent in the thesis's main body discussions on BCTs and PSD principles, and is often referred to as cues, prompts or reminders. This area of study has been growing in recent years with advancements and ongoing research into the incorporation of Just-In-Time-Adaptive-Interventions (JITAIs), machine learning and artificial intelligence in delivering effective and persuasive mHealth physical activity behaviour change intervention apps.

#### 4.4.2.2.3 The Persuasive Systems Design Model (PSDM)

Oinas-Kukkonen and Harjumaa (2009) criticise the lack of descriptive power and practical guidance provided by The Functional Triad (Fogg, 2003) and The Fogg Behavioural Model (FBM) (Fogg, 2009). More specifically, the lack of guidance for how persuasive designers can analyse, design and evaluate characteristics for persuasive technologies, including the mHealth intervention app mode of digital delivery. For this reason, Oinas-Kukkonen and Harjumaa (2009) developed the theoretical and conceptual Persuasive Systems Design Model (PSDM), a framework (based on empirical work and theory) that can be used to inform the design and evaluation of the content, functionality and design (user interface) software features of persuasive systems, such as mHealth physical activity behaviour change intervention apps. Figure Appendix F.5 illustrates Oinas-Kukkonen and Harjumaa's (2009) PSDM.

The PSDM aims to enrich the design, development and evaluation of persuasive systems as a means to enhancing the potential persuasive the design of persuasive systems can have on influencing attitudinal and behavioural change. The PSDM is comprised of three distinct phases: (1) understanding the key issues behind persuasive systems, (2) analysing the persuasive context, and (3) (selecting) persuasive design qualities that can be used to inform the design and/or evaluation of a persuasive system (Oinas-Kukkonen and Harjumaa, 2009). Brief descriptions of these phases are discussed below. Of particular relevance to the thesis is the third phase, which includes 28 PSD principles (detailed in Table 4.1 in the thesis's main body discussion in Subsection 4.4.2).

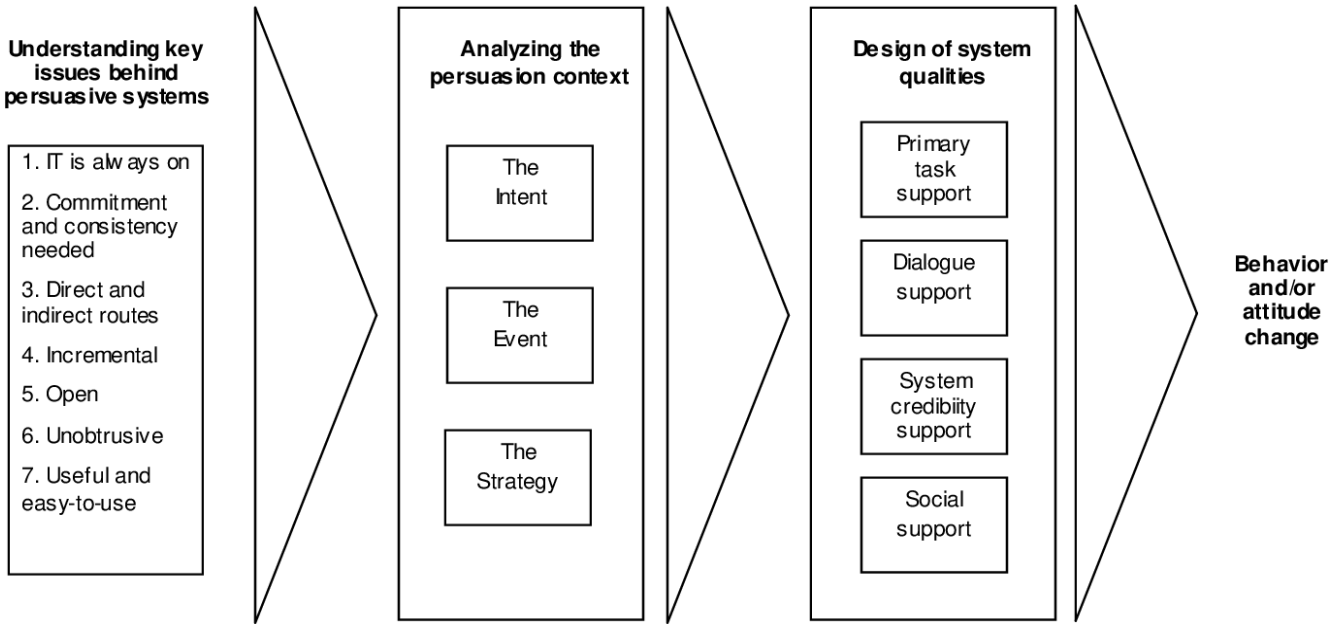



*Figure Appendix E.5: The Persuasive Systems Design Model (PSDM) [Source: Oinas-Kukkonen and Harjumaa (2009)]*

The *first phase* identifies seven postulates behind persuasive technology "which implicitly cover a multitude of aspects that need to be recognized when designing persuasive systems" (Oinas-Kukkonen and Harjumaa, 2009, p.491). These postulates are defined below with regard to their relevance to evaluating the design of mHealth physical activity behaviour change intervention apps (Oinas-Kukkonen and Harjumaa, 2009):

1. **Persuasive systems are "never neutral", but rather "always on"**
   Evaluating whether a mHealth physical activity app is multi-phased and adaptable to the behavioural change process. For example, adapting to a user's different goals, whether to count calories burnt, record physical activity levels, monitor heart rate, track weight, etc.
2. **People like their worldviews to be consistent and organised**
   Evaluating whether a mHealth physical activity app provides opportunities for commitment, supports cognitive consistency, and ensures consistent representational displays.
3. **Using direct and indirect routes as key persuasive strategies**
   Evaluating whether a mHealth physical activity app provides sensory cues and information that enables both direct and indirect processing, such as the availability of sufficiently detailed information and shortcuts respectively.
4. **Persuasion is incremental**
   Evaluating whether a mHealth physical activity app is designed in a way that enables and supports behaviour change as an incremental process. For example, encouraging inactive individuals to first start walking more, before encouraging high-intensity exercises.

5. **Persuasion should always be open**

   Evaluating whether an app designer's bias is effectively communicated through the design of the app. In other words, ensuring that the translation of the persuasive objective is truthful (not coercive or deceptive), is not based on false or untruthful information, and minimising the possibility that users might perceive and interpret the app as harmful or unethical.

6. **Persuasive systems should be unobtrusive**

   Evaluating whether a mHealth physical activity app is not designed in a way that causes unnecessary or excessive disturbance when people are participating in a physical activity, or carrying out other daily tasks. At the same time careful consideration should be given to identifying opportune (and inopportune) moments for persuading individuals towards physical activity, and how to optimally design and communicate these persuasive cues.

7. **Persuasive systems should aim to be both useful and easy to use**

   Evaluating various design-related characteristics by ensuring a mHealth physical activity app lacks errors, is easy of access, provides credible information quality, is attractive, promotes usability and user loyalty, and also creates for positive user experiences.

Persuasive systems designers should ensure these seven postulates are considered when evaluating the persuasive design of mHealth physical activity behaviour change intervention apps (Oinas-Kukkonen and Harjumaa, 2009).

In the *second phase*, three core components (consisting of seven elements) are described to help persuasive designers better understand the elements comprising a given persuasive context (Oinas-Kukkonen and Harjumaa, 2009). These elements will also be related to evaluating the design of mHealth physical activity behaviour change intervention apps.

1. **The intent of the persuasion**

   The specific behaviour (or attitude) that the designer (persuader) deliberately intends to persuade and change in a user (persuadee) interacting with a mHealth physical activity app.

   - **Persuader:** the designer who intentionally seeks to change a user's attitudes and behaviours regarding physical activity.
   - **Change type:** evaluating the type of attitudinal or behavioural change invoked through the design of a mHealth physical activity app.

2. **The event in which the persuasion occurs**
    - **Use context:** features arising from the problem domain (i.e. physically inactive individuals) that can be potentially addressed through the design of a mHealth physical activity app.
    - **User context:** evaluating whether the design of a mHealth physical activity app targets users (persuadees) in terms of their needs, goals, social support structure, commitment, lifestyle, preferences, and other relevant target market characteristics. Of these factors, goal setting, user preferences and social support structures are greatly leveraged in the design of mHealth physical activity apps. Evaluations should also assess how physical activity behaviour change strategies and BCTs are translated into persuasive (user interface) design features and how information and sensory content is conveyed through mHealth physical activity apps.
    - **Technology context**: evaluating whether a mHealth physical activity app is designed effectively with regard to the particular channel and platform through which the intervention intends to be delivered. In the case of mobile and tablet apps, the design of persuasive principles and app design features should be evaluated with the strengths and weaknesses of the operating system in mind, as well as consideration for other potential risks and opportunities.
3. **The persuasive (physical activity behaviour change) strategy**
    - **Message:** evaluating whether the form and content of information, features and symbols are designed effectively for persuading the persuadee to engage further with the app and use it as a supportive and motivational tool for physical activity behaviour change.
    - **Route:** evaluating whether a mHealth physical activity app provides both direct and/or indirect routes for information processing when appropriate and necessary.

The *third phase* of the PSDM identifies 28 PSD principles that are classified into four categories: (1) primary task support, (2) dialogue support, (3) system credibility, and (4) social support (Oinas-Kukkonen and Harjumaa, 2009). Persuasive app designers can select either of these PSD principles (or combinations thereof) to inform the design and/or evaluation of persuasive systems, such as mHealth physical activity behaviour change intervention apps. Given the importance of these 28 PSD principles in this thesis, their descriptions and examples of their application in the context of mHealth physical activity behaviour change intervention apps is provided in Table 4.1 in the thesis's main body discussion in Subsection 4.4.2.

# Appendix F (Chapter 4): A (Preliminary) Critical Review of Multi- and Interdisciplinary Approaches

## 4.4.3 Approaches to Designing, Developing and Evaluating Consumer mHealth Behaviour Change Intervention Apps: Challenges and Opportunities: A (Preliminary) Critical Review of Multi- and Interdisciplinary Approaches

A critical review of nine holistic multi- and interdisciplinary approaches is provided in this Appendix F. The nine approaches, which propose combining and amalgamating the health behavioural sciences and information systems perspectives, are listed and referenced in Table 4.2. Notably, this critical review is not exhaustive. The primary purpose of conducting the critical review was to identify strengths and weaknesses of the current knowledge base on holistic multi- and interdisciplinary approaches, and more importantly, to identify knowledge gaps that can be improved upon in terms of addressing the thesis problem. The problem being the lack of approaches for guiding the multi- and interdisciplinary collaborative design of mHealth behaviour change intervention apps, specifically for physical activity.

| **Holistic Multi- and Interdisciplinary Approaches: A Preliminary Critical Review** | | |
|---|---|---|
| **No.** | **Name of Approach** | **Reference** |
| 1 | The CeHRes Roadmap | Van Gemert-Pijnen, et al. (2011) |
| 2 | The Digital Intervention Development Approach | Bradbury, et al. (2014) |
| 3 | The BIT Model | Mohr, et al. (2014) |
| 4 | The IDEAS Framework | Mummah, et al. (2016) |
| 5 | The mHealth Intervention Development and Evaluation Process | Whittaker, et al. (2012) |
| 6 | The CDE Framework | Johnston, et al. (2015) |
| 7 | The mHealth Intervention Development Process | Smith, et al. (2016) |
| 8 | A Holistic Approach to mHealth Intervention Design | Wang, et al. (2017) |
| 9 | The Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps | Geuens, et al. (2016) |

*Table 4.2: Holistic Multi- and Interdisciplinary Approaches: A Preliminary Critical Review [Source: Researcher's own construction]*

#### 4.4.3.1 A (Preliminary) Critical Review of Multi- and Interdisciplinary Approaches

The (preliminary) critical review is divided into subsections orientated towards each holistic multi- and interdisciplinary approach listed in Table 4.2. Within each subsection, critical cross comparisons are drawn, noting strengths and limitations. The key critical findings inform the knowledge gaps and opportunities for future research, which are incorporated in the thesis's main body discussion in Chapter 4, Subsection 4.4.3.

***The CeHRes (the Centre for eHealth Research) Roadmap (van Gemert-Pijnen, et al., 2011)***

A well-recognised and evidence-based holistic eHealth technology framework is *The CeHRes (the Centre for eHealth Research) Roadmap*, which fundamentally emphasises the interdependencies between human characteristics, technology and the larger socioeconomic environment (van Gemert-Pijnen, et al., 2011). It emphasises a multidisciplinary approach to the development of eHealth technologies that are engaging, interactive and persuasive (van Gemert-Pijnen, et al., 2011). It also emphasises the need for designing eHealth technologies that are in accordance with the health context and the needs, preferences and determinants of the targeted population group (van Gemert-Pijnen, et al., 2011). Based on a review of the strengths and limitations of sixteen eHealth technology frameworks, the CeHRes Roadmap is grounded by six working principles, which describe the nature of eHealth technology (van Gemert-Pijnen, et al., 2011). These six principles are that eHealth technology development: (1) is a multidisciplinary participatory process; (2) involves systematic, continuous and iterative formative and summative prototype evaluation cycles; (3) is intertwined with implementation; (4) should involve persuasive systems design principles; (5) requires robust and advanced methods for assessing usage and clinical impact; and (6) allows for changes in the healthcare delivery process (that is, in referring to and aligning with the afore-discussed paradigm shifts in the digital health revolution) (van Gemert-Pijnen, et al., 2011).

The CeHRes Roadmap has five development activities or stages (van Gemert-Pijnen, et al., 2011). These are: (1) contextual inquiry; (2) value specification; (3) design; (4) operationalisation; and (5) summative evaluation (van Gemert-Pijnen, et al., 2011). Four formative evaluation cycles iterate throughout each stage of the whole development process, and an account is given to factors relating to users' requirements, prototyping, value drivers and the underlying business model (van Gemert-Pijnen, et al., 2011). In comparison to other multidisciplinary approaches, such as Mohr, et al. (2014), Mummah, et al. (2016), and others,

the CeHRes Roadmap holds a strength in that it includes consideration for a value specification. Whilst the CeHRes Roadmap serves as a valuable contribution to guiding a multidisciplinary and human- and user-centred design approach to eHealth technology development, it can be criticised for its omission of intervention Behaviour Change Techniques (BCTs) (Michie, et al., 2008; 2011; 2013). It has also been criticised for being too broad in scope, which ultimately discounts for the design and evaluation intricacies pertinent to specific modalities and platforms of intervention delivery (such as mobile apps (Michie, et al., 2008; 2013).

***The Digital Intervention Development Approach (Bradbury, et al., 2014)***

Bradbury, et al.'s (2014) proposed *The Digital Intervention Development Approach*, in comparison to the CeHRes Roadmap, provides a methodological guide that emphasises the importance in considering which modality and digital platform an intervention will be delivered. Bradbury, et al.'s (2014) approach highlights that depending on technological capabilities, the selected platform can largely influence and constrain how an intervention can be designed, developed and evaluated. For example, smartphones and tablets have smaller screens in comparison to large screen desktop computers, which will restrict the complexity and extent of information that can be displayed on mobile device based apps (Bradbury, et al., 2014). While the consideration for selected modality falls under Bradbury, et al.'s (2014) second step, his first step is similar to that of the CeHRes and several other frameworks (Bartholomew, 2011; Mohr, et al., 2014; Bartholomew Eldredge, et al., 2016; Mummah, et al., 2016; Kok, Peters and Ruiter, 2017). This similar first step suggests that the target health behaviour (such as physical activity) be identified at the initial outset (Bradbury, et al., 2014).

After the key user behaviours and modality of delivery are selected, Bradbury, et al. (2014) suggests the digital intervention be developed based on a combination of deductive and inductive approaches. Deductive approaches review existing literature and theory to elicit the BCTs that have already shown to be effective at targeting a specific behaviour, and are thus evidence-based. Inductive approaches allow for exploration and gathering of user's perceptions and past experiences in determining which intervention components and BCTs will be deemed preferable, feasible and acceptable for targeting a particular behaviour for a specific target group. These deductively and inductively elicited techniques then constitute the creation of the intervention plan, which is followed by an iterative approach to usability and user experience testing, after which RCTs are conducted as the final step in assessing the full feasibility and effectiveness of the intervention (Bradbury, et al., 2014).

While Bradbury, et al.'s (2014) Digital Intervention Development Approach is more specific, simplified and attentive to the modality of intervention delivery, in comparison to the CeHRes Roadmap, Bradbury, et al. (2014) only make reference to two types of usability testing, namely think-aloud interviews and retrospective interviews, which is limited. In addition, consideration is not articulated as to the time concerns and limitations regarding the conducting of long-term RCTs (Klasnja, Consolvo and Pratt, 2011; Poole, 2013; Bothwell, et al., 2016; Murray, et al., 2016). Although a suggestion is made for conducting manageable "small scale" RCTs (Bradbury, et al., 2014, p.5), albeit "small scale" RCTs are likely to be criticised by professionals from the Health Behavioural Sciences perspective.

A strength is that Bradbury, et al. (2014) integrates qualitative and quantitative (and triangulated) mixed method approaches during the testing phases. However, unlike the CeHRes Roadmap, this mixed methods guide fails to account for the increasingly-recognised need for human- and user-centred design approaches to eHealth and mHealth behaviour change intervention design, which is a limitation (Poole, 2013; Yardley, et al., 2015a; 2015b; Schnall, et al., 2016; Smith, et al., 2016; Faiola and Holden, 2017; Michie, et al., 2017). In addition, while the Digital Intervention Development Approach does account for the mode of intervention delivery and suggests consideration be given to the technical capabilities of a platform in guiding an intervention's design, development and evaluation, it remains too broad for providing practical guidance specific to the design of mHealth behaviour change intervention apps in particular. Moreover, Bradbury, et al.'s (2014) approach fails to incorporate the perspective lens of persuasive technology and persuasive software design principles, which van Gemert-Pijnen, et al. (2011, p.13) emphasise are "... needed to understand how technology can motivate or inspire healthy behaviours [and] how technology fits with the needs of users".

***The Behavioural Intervention Technology (BIT) Model (Mohr, et al., 2014)***

To provide intervention designers with more guidance in terms of how to design eHealth and mHealth behaviour change interventions, Mohr, et al. (2014) proposed *The Behavioural Intervention Technology (BIT) Model*. The BIT Model is a hybrid framework that defines both the conceptual and technological architecture of a behavioural intervention technology (BIT) by combining behavioural science principles with technological design features (Mohr, et al., 2014). Mohr, et al.'s (2014) hybrid framework was one of the first holistic approaches that combined the health behavioural sciences and information systems perspectives.

Based on a critical review of some well-verified persuasive technology frameworks including the Fogg Behavioural Model (FBM) (Fogg, 2009), the Persuasive Systems Design Model (PSD Model) (Oinas-Kukkonen and Harjumaa, 2009), two BCT taxonomies (Michie, et al., 2011; 2013), Mohr, et al.'s (2014) model is distinct in that it separates out a theoretical (conceptual) level and an instantiation (technical implementation) level. Using the BIT Model, designers should be able to answer the following questions: *why* they want to develop an intervention (conceptual clinical aims versus usage aims); *how* behaviour change can be achieved (the conceptual use of BCTs); *what* BIT elements to use (the translation and operationalisation of BCTs into software elements); and delivery in terms of *how* (the technical characteristics that optimise the BIT elements and enhance user engagement) and *when* (the workflow governing when and under what circumstances the intervention and its strategies are delivered).

Unlike other frameworks, models and processes, such as van Gemert-Pijnen (2011), Whittaker, et al. (2012) and Bradbury, et al. 2014), Mohr, et al.'s (2014) BIT Model also provides what they term *The BIT-Tech Framework.* The BIT-Tech Framework is an instantiation protocol for translating the conceptual BIT design into digital technology form. In other words, The BIT-Tech Framework guides system designers and developers in implementing the BIT by considering the relationships between the BIT software components (technological software and user interface design features), the user (person interacting with the digital intervention), and the environment (location and time in which the intervention is used) (Mohr, et al., 2014). The four components of the BIT-Tech include the (1) profiler, (2) intervention planner, (3) intervention repository and (4) user interface. Ultimately, once the BIT system is developed, Mohr, et al. (2014) suggests the application of human-computer interaction (HCI) evaluation methods in assessing the usability, ease of use and usefulness of the technology.

In terms of strengths, Mohr, et al. (2014) recommends consideration be given to other system-related software quality aspects such as the security, maintainability, reliability and efficiency of the technological platform. Another strength is that Mohr, et al.'s (2014) BIT Model is built on and integrates existing credible, reliable and empirically-tested theories and frameworks from both the Health Behavioural Sciences and Information Systems disciplines (such as the BCT Taxonomy, FBM and PSDM. In addition, Mohr, et al.'s (2014) BIT Model provides designers with more granular practical guidance on how to translate behavioural intervention strategies into BIT elements and technical characteristics expressed as software and user interface design features in a technological platform, which many other multidisciplinary

approaches do not provide (such as The CeHRes Roadmap and The Digital Intervention Development Approach).

As both a strength and limitation, in comparison to other approaches reviewed, Mohr, et al.'s (2014) model acknowledges but does not explicitly state the need for conducting clinical testing evaluations such as gold standard RCTs. Professionals from the health behavioural sciences perspective may perceive this as undermining the importance and value they place on long-term RCTs, which they perceive as necessary for assessing the objective clinical and behavioural change effectiveness of health interventions (Jacobs and Graham, 2016; Murray, et al., 2016).

In terms of limitations, The BIT Model and The BIT-Tech Framework lack integration of design processes, such as human- and user-centred design, and proposes a simplified model, which the authors recognise and argue as "a general framework" that requires modification and elaboration to guide the instantiation of specific BITs (Mohr, et al., 2014, p.7). In addition, while Mohr, et al. (2014) recognises the relevance of behavioural and psychological theories (such as SCT and TPB), their acknowledgement is brief, and these theories are excluded from final BIT Model. Mohr, et al.'s (2014) argument for this is that although "behavioural and psychological theories provide guidance regarding the relationship between user behaviours and the attainment of ultimate treatment goals and may be helpful in determining proximal intervention aims, they are less helpful in guiding the development of elements, characteristics and workflow". This justification holds relevance in that although frameworks, models and processes in both the information systems and health behavioural sciences perspectives are fundamentally based on and informed by underlying behavioural and psychological theories, there exist knowledge gaps and pragmatic steps in transitioning from and translating and operationalising these theories into digital behaviour change intervention features and elements.

Crutzen's (2014, p.1) critical review of Mohr, et al.'s (2014) knowledge contribution leads to the suggestion that The Intervention Mapping (IM) Approach (Bartholomew, et al., 2011) can be combined with The BIT Model to achieve what he refers to as "the best of both worlds". He justifies this recommendation by arguing that there are steps within both The IM Approach and The BIT Model that addresses the limitations of existing models. Yet, despite the considerable overlap between them, both models offer a valuable contribution to advancing research in this multi- and interdisciplinary area: The IM Approach stresses the importance of parameters for

intervention use, and The BIT Model focuses on the technical instantiation of these interventions (Crutzen, 2014).

Another criticism is Wang, et al.'s (2017) comment on Mohr, et al.'s (2014) second theoretical question which seeks to answer '*how* the behaviour change can be achieved', and provides designers with guidance on conceptualising and choosing appropriate and potentially effective evidence-based BCTs. While Mohr, et al (2014) suggests these strategies are selected from Michie, et al.'s (2011; 2013) two BCT taxonomies, Wang, et al. (2017, p.13) "think [that] including the PSD Model can enrich this". This is an intriguing critique, suggesting Wang, et al. (2017) views BCTs and PSD principles as possibly existing on par, hence implying that BCTs and PSD principles are comparable, interchangeable and perhaps potentially synonymous, albeit perceived differently from the health behavioural sciences and information systems perspectives, respectively.

There are multi-faceted complexities involved in addressing these theory and design related issues when providing guidance to multidisciplinary teams for designing, developing and evaluating digital health behaviour change interventions. This is further complicated by the wicked and challenging nature of achieving effective collaborative teamwork in this newly evolving multi- and interdisciplinary arena (Lathia, et al., 2013; van Velsen, et al., 2013; Geuens, et al., 2016; Hekler, et al., 2016; Vos, et al., 2016; Yardley, et al., 2016b; Michie, et al., 2017). Mohr, et al.'s (2014, p.1) argues for the current "lack of models to inform the design of behavioural intervention technologies" such as mHealth (promotion) behaviour change intervention apps. Furthermore, Mohr, et al. (2014, p.1) recognises the need for more theoretical frameworks, models and protocols that support a multi- and interdisciplinary approach to technology-based intervention design, development and evaluation, and attempts to address this by "bridg[ing] the fields of behavioural science and technology".

***The Integrate, Design, Assess and Share (IDEAS) Framework (*Mummah, et al., 2016)**

Following the same sentiments of Crutzen (2014) to combine "the best of both worlds", Mummah, et al. (2016, p.2) propose *The Integrate, Design, Assess and Share (IDEAS) Framework* (and toolkit of strategies) which aims to consolidate the "best combination of approaches available" from both the health behavioural sciences and information systems perspectives. The IDEAS Framework consists of ten phases: (1) empathise with target users, (2) specify target behaviour, (3) ground in behavioural theory, (4) brainstorm and ideate

implementation strategies and features, (5) prototype potential solutions, (6) gather user feedback on prototypes, (7) build a fully functional minimum viable product, (8) pilot test to assess potential efficacy and usability, (9) evaluate efficacy in an RCT, and (10) share intervention and findings. These ten phases are categorised into four overarching groups: Integrate, Design, Assess and Share (IDEAS) (Mummah, et al., 2016). Mummah, et al. (2016) also proposes three strategies for applying IDEAS in practice by: (1) employing a multidisciplinary team; (2) using a flexible, iterative and creative approach; and (3) transitioning between divergent and convergent thinking processes for idea generation and solution refinement.

Although Mummah, et al.'s (2016) IDEAS Framework is intended to be holistic and multi/interdisciplinary in nature, it portrays a heavier tendency towards the information systems perspective. This is demonstrated through a few ways: the preference for understanding the ways in which intervention theory, techniques and strategies are conveyed as software features in behaviour change apps (phases 2, 3 and 4); the iterative and rapid prototyping approach using sketches and "clickable mockups of digital interfaces" (phase 5); the orientation towards a traditional user-centred systems design (Norman and Draper, 1986) approach for prototype usability testing and user feedback gathering (phase 5 and 6); and recommended use of usability interviews and satisfaction questionnaires that can help "identify usage patterns" and "lend insight into preferred features, problematic or confusing user flows" and enquire whether users find an "app easy to use" (Mummah, et al., 2016, p.5). The tendency towards an information systems perspective is also exhibited in Mummah, et al.'s (2016) examples relating to the use of app features such as photograph taking for capturing and record self-monitored physical activity (a software feature translation of the commonly used "self-monitoring" BCT).

In terms of strengths, The IDEAS Framework offers a novel contribution its hybridisation of existing models: evidence-based behavioural theory (such as SCT, Self-Efficacy Theory, HBM and TTM); qualitative inquiry (Yardley, et al., 2015a; 2015b); theory- and evidence-based BCTs from Michie, et al.'s (2011; 2013) two BCT taxonomies; design thinking (Stanford Institute of Design, 2010; Chasanidou, Gasparini and Lee, 2015); behavioural science-informed user experience design (Hekler, et al., 2011); and intervention prototype testing, evaluation and dissemination (Whittaker, et al., 2012; Brown, et al., 2013). Other strengths of The IDEAS Framework include its rapid, iterative approach to intervention design and prototyping, integration of user insights and feedback throughout, encouragement for the inclusion of theory-driven and evidence-based behavioural theories and BCTs, and its emphasis on the importance

of conducting rigorous RCT evaluations for assessing objective and measurable behavioural outcomes.

Furthermore, IDEAS offers a flexible pragmatic application with Mummah, et al. (2016, p.5) explaining that "IDEAS phases are more like a system of overlapping spaces, rather than a sequence of orderly steps". Additional flexibility is also offered in the elastic use of methods within the ten phases. Examples include: qualitative target user research methods such as observations, focus groups, interviews and questionnaires (phase 1); informal conversations, usability testing, surveys, semi-structured or in-depth qualitative interviews (phase 6); and the use of analytics such as Just-In-Time, Adaptive Interventions (JITAIs) (phase 7) (Mummah, et al., 2016). The iterative approach, as similarly advocated for in some other approaches (Whittaker, et al., 2012; Johnston, et al., 2015; Smith, et al., 2016) is imperative for the design, development and evaluation of effective mHealth behaviour change intervention apps. This is specifically given "the rapid pace of new technology development [which] makes it increasingly difficult for researchers to develop, pilot-test and evaluate interventions before such technologies become outdated or obsolete" (Kisner, 2013; Mummah, et al., 2016, p.1).

In terms of limitations, upon first review, it becomes apparent that the (supposed strength of the) flexibility of The IDEAS Framework may be paradoxical in that it makes it more challenging for novice intervention designers to effectively apply the suggested phases and methods. Additionally, the behaviour change strategies are not exhaustive, and the framework does not suggest the randomised evaluation of isolated intervention component techniques (Collins, Murphy and Strecher, 2007; Klasnja, Consolvo and Pratt, 2011; Klasnja, et al., 2017). It can however be argued that strategies and BCTs work best together and thus isolated evaluations may not be necessarily as advantageous in the application of this particular framework. Moreover, The IDEAS Framework emphasises the importance of "design" in developing effective digital health behaviour change interventions, yet it fails to acknowledge, review or incorporate the perspectives and principles of persuasive technology the PSDM. Persuasive technology and the PSDM are becoming increasingly recognised in their power to inform the design of persuasive and effective digital health behaviour change interventions targeting individuals as app users and (Langrial, et al., 2012; Orji, 2014; Geuens, et al., 2016; Knittle, et al., 2016; Almutari and Orji, 2019; Haque, 2020; Sporrel, et al., 2021).

Another concern with Mummah, et al.'s (2016) IDEAS Framework is the potential for misinterpretation, misunderstanding and possible conflict with regard to the differing

worldviews, assumptions, beliefs, goals and objectives of various contributors within the suggested multidisciplinary team approach. They explain that digital health behavioural intervention is an "inherently transdisciplinary endeavor" (Mummah, et al., 2016, p.5) and that "engages multidisciplinary perspectives though a cross-sector team" (Mummah, et al., 2016, p.3). Yet, they fail to recognise and explicitly articulate that their interpretations of and meanings derived from their use of terminology including 'user acceptance', 'design', 'evaluate', 'usability', 'user satisfaction', 'user experience', 'motivation', 'user enjoyment', 'efficacy' and 'effectiveness' are predominantly interpreted and made sense of through an information systems perspective. These terms can be shared and used synonymously between two perspectives, which is apparent for example in Yardley, et al.'s (2015a) Person-Based Approach. Critical investigation and examination uncovers differences in the underlying worldview assumptions, beliefs, interpretations, meanings, goals, objectives, theories, frameworks, methodological approaches, and processes between the health behavioural sciences and information systems perspectives. When these different perspectives and interpretations of meaning are left unacknowledged and unclarified, challenges can arise in multi- and interdisciplinary collaborative teamwork, particularly in terms of conflicts and disagreements.

On another note, in comparison to other digital health behavioural change intervention frameworks and processes, which offer guidance for eHealth and mHealth in general (such as van Gemert-Pijnen, et al., 2011; Bradbury, et al., 2014; Mohr, et al., 2014; Bartholomew Eldredge, et al., 2016), The IDEAS Framework originated from the iterative development of a consumer mHealth app intervention design specifically. Although Mummah, et al. (2016) does state that IDEAS can be adopted for application in eHealth and other digital health behaviour change interventions. Designing for mHealth behaviour change intervention apps is distinguishable from other types of eHealth and digital health intervention platforms because there are particular characteristics, capabilities, technical features, functionalities, and user interface display considerations that are particular to mobile devices and mobile-based apps (Lathia, et al., 2013; Helf and Hlavacs, 2016; Cameron, Ramaprasad and Syn, 2017; Wang, et al., 2017).

Most multi- and interdisciplinary eHealth and digital health behaviour change interventions in general fail to provide sufficient platform-specific guidance and practical support for designers in the design, development and evaluation of mHealth interventions and mHealth (promotion) behaviour change intervention apps. Frameworks, approaches and processes for guiding

mHealth interventions and mHealth behaviour change intervention app design, development and evaluation have thus been proposed to address this knowledge gap. These include (in order of argument, not chronological order): Whittaker, et al (2012), Johnston, et al. (2015), Smith, et al. (2016), Wang, et al. (2017), and Geuens, et al. (2016).

***The mHealth Intervention Development and Evaluation Process (Whittaker, et al., 2012)***

Whittaker, et al. (2012) proposed *The mHealth Intervention Development and Evaluation Process*, which is suitable for guiding the design of several mobile device formats including online websites, native apps, text and video messaging services. The process includes several steps: (1) conceptualisation, (2) formative research for informing development, (3) pretesting, (4) pilot studies, (5) pragmatic RCTs, and (6) further qualitative research to inform the ongoing improvement and implementation (Whittaker, et al., 2012). Along with each step, Whittaker, et al. (2012) propose several elements and methods. Conceptualisation considers the target behaviour, intervention objective, intervention format, intervention content and behaviour change theory. Formative research for informing the mHealth intervention's development can utilise focus groups and online surveys. Pretesting can use focus groups, online surveys and individual interviews. Pilot studies can be small and non-randomised trials. Pragmatic RCTs tend to be small and community-based. Further qualitative research to inform the ongoing improvement and implementation can utilise semi-structured interviews and online surveys.

A strength of Whittaker, et al.'s (2012) mHealth intervention process are four underlying cross cutting themes. Firstly, the integrity of evidence-based behaviour change theory (such as SCT and Self-Efficacy Theory) is considered throughout the process and incorporated in each step. Secondly, the importance of involving the target audience from the outset is suggested to ensure the intervention is engaging and useful. Thirdly, allowing for continuous improvements based on participant feedback. Fourthly, allowing for a general focus on how the intervention can be implemented from the beginning.

A simultaneous strength and limitation of Whittaker, et al.'s (2012) mHealth Intervention Development and Evaluation Process is the suggestion to conduct pragmatic RCTs with real participants in real-world settings. On the one hand, this suggestion to conduct trials (such as RCTs) is a strength. It is advantageous in that RCTs are the described as the "gold standard" because they allow for the objective measuring and evaluating of health behavioural and physiological outcomes, and can help identify any potential adverse and unintended effects (Klasnja, Consolvo and Pratt, 2011, p.3066; Bothwell, et al., 2016, p.2175). However, on the

other hand, Whittaker, et al.'s (2012) proposes that these RCTs be less formalised and smaller in scale, which can potentially reduce the time and resources required to perform and analyse. Proposing a less formalized RCT-like method would likely be criticised by professionals from the health behavioural sciences perspective, who unwaveringly value long-term rigorous RCTs above all other forms of trial methods.

In terms of limitations, the approximated time required to carry out Whittaker, et al.'s (2012) process is notable concern, especially when it comes to the quickly changing and advancing digital technology space, where quick design, development and evaluation iterations are more suitable (Haselmayr, 2013; Kisner, 2013). Another limitation is that Whittaker, et al.'s (2012) process does not consider the power of persuasive technology and persuasive systems design. Furthermore, Whittaker, et al.'s (2012) process does not provide pragmatic guidance for how intervention strategies and BCTs can be translated and operationalised into technical and interactive mobile elements and user interface features.

Despite these concerns and limitations, Whittaker, et al.'s (2012) mHealth Intervention Development and Evaluation Process offers a notable contribution to the knowledge base, and is one of the first of its kind (particularised to mHealth) given the time stamp. It is also a noteworthy contribution considering its emphasis on the underlying integration of health behaviour change theories and incorporation of BCTs in mHealth interventions. A remaining issue though is that Whittaker, et al.'s (2012) process applies to several formats of mHealth intervention delivery, and hence does not incorporate considerations for the mobile app platform specifically, illustrating the persisting gap for research on frameworks and approaches for mHealth behaviour change intervention apps in particular.

### *The Clarify, Design and Evaluate (CDE) Framework (Johnston, et al., 2015)*

To address this persisting knowledge gap, Johnston, et al. (2015) proposed *The Clarify, Design and Evaluate (CDE) Framework*. The CDE Framework was developed by a multidisciplinary team of technologists, clinicians, researchers and software developers at the Imperial College London, and aims to provide a simplified three-phase user-centred design approach to mHealth app development (Johnston, et al., 2015). Similarly to the holistic multi- and interdisciplinary approaches discussed above, The CDE Framework's first phase, *Clarify*, aims to identify and understand more about the health-related problem, gather user requirements, determine the potential role for the mHealth solution and establish system (app) requirements (Johnston, et al., 2015). This stage utilises both qualitative and quantitative research methods including

literature reviews, user experience research, observational studies, semi-structured and structured interviews (Johnston, et al., 2015).

The second phase, *Design*, uses the Plan, Do, Study, Act (PDSA) cycle to design and develop the mHealth app solution (Johnston, et al., 2015); a cycle recommended by the NHS Institute for Innovation and Improvement (Taylor, et al., 2014). The PDSA involves a rapid and iterative design-test-refine process that allows for quick wireframing, prototyping, end user testing and data collection cycles. In comparison to the other holistic approaches discussed thus far, the application of the PDSA cycle is significantly relevant and valuable to app prototype development since it provides designers the opportunity to perform several iterative test and refinement sprints that require considerably less time than formal evaluation methods (Lathia, et al., 2013; Jacobs and Graham, 2016).

The third phase, *Evaluate*, begins as soon as a minimal viable product (MVP) is produced from the PDSA Design phase (Johnston, et al., 2015). This evaluation process is more formal than the PDSA's testing cycle as it aims to assess the overall effectiveness of the mHealth app in either simulated environments or real-life clinical settings (that is, RCTs). This stage also requires more time, considering that formal ethical approval is required (for pilot testing and long-term control studies), cost-effectiveness calculations are performed, and extensive stakeholder consultation and feedback is sought (Poole, 2013; Bothwell, et al., 2016).

In comparison to other frameworks (Bartholomew, et al., 2011; van Gemert-Pijnen, et al., 2011; Bradbury, et al., 2014; Bartholomew Eldredge, et al., 2016) which involve external stakeholders (such as health practitioners, patients, managers, organisational finance and technology divisions) from the early development stages, Johnston, et al.'s (2015) CDE Framework only suggests stakeholder involvement in the final phase. This is both a strength and limitation. On the one hand, it aims to save time during the conceptualisation and design stages, and allow for designers to reach the PDSA cycle within a shorter time frame, where rapid iterative design-test-refine cycles can soon produce a MVP for final end-user and stakeholder evaluation. On the other hand, only involving stakeholders at the end may be risky since the final product may not necessarily meet all of the stakeholders' wants and needs, and thus may ultimately negatively impact on the project's time and resources. Although Johnston, et al.'s (2015) approach is open to the risk of having to return to phase one and starting again, this risk can be avoided.

Johnston, et al.'s (2015) attempt to reduce time is an important consideration in the mHealth app area. With the rapidly evolving digital revolution and daily advances in mobile technologies, and in light of the large volume of (Android and Apple) mHealth consumer apps available for public download, designers cannot afford to adopt and undertake digital intervention development approaches that require one to four years to implement (Lathia, et al., 2013; Mummah, et al., 2016;). Accordingly, Johnston, et al.'s (2015) attempts to simplify the process and save time and resources has good intention and is a knowledge gap and opportunity that requires ongoing future research. Another strength is Johnston, et al.'s (2015) incorporation of the PDSA cycle, which other approaches have not considered.

In terms of limitations, Johnston, et al.'s (2015) CDE Framework fails to acknowledge the importance of BCTs, does not consider underlying health behaviour change theories, and fails to provide designers with practical guidance for translating and operationalising intervention components and BCTs into app software features. The CDE Framework, as like Whittaker, et al.'s (2012) approach, does not consider for the role of PSD in designing, developing and evaluating effective and persuasive mHealth intervention apps; shown to positively motivate, support and encourage individuals' health behaviour change (Langrial, et al., 2012; Kasali, et al., 2017; Langrial, et al., 2017; Geuens, et al., 2019).

***The mHealth Intervention Development Process (Smith, et al., 2016)***

Smith, et al. (2016) proposes *The mHealth Intervention Development Process*, which addresses some of the design and theory limitations identified in Johnston, et al.'s (2015) CDE Framework. More specifically, Smith, et al.'s (2016) process considers health behaviour change theories, BCTs and PSD; all of which are imperative to the design of smartphone apps that can effectively deliver engaging and persuasive mHealth behaviour change intervention apps (Kisner, 2013; Geuens, et al., 2016; Wang, et al., 2017). Based on Whittaker, et al.'s (2012) process, Smith, et al. (2016) draws from existing multidisciplinary research and literature to forming an enhanced systematic, comprehensive and integrated process to mHealth app development.

Smith, et al.'s (2016) mHealth Intervention Development Process comprises four main stages: (1) conceptualisation, (2) formative research and pretesting, (3) pilot trials, and (4) evaluation trials. The first stage, conceptualisation, has three sub-stages: (1) understand the behaviour (divided into four steps: define the problem in health behavioural terms, select the target behaviours, specify the target behaviours, and identify what needs to change; (2) identify the

intervention options (such as persuasion, enablement, environmental restructuring, coercion, incentivisation, modelling, education and training); and (3) identify the content and implementation options (which includes two steps: identifying the BCTs; and identifying the mode of delivery) (Smith, et al., 2016). The conceptualisation sub-stage draws from the evidence-based framework, The Behaviour Change Wheel (BCW) (Michie, van Stralen and West, 2011; Michie, Atkins and West, 2014). The fourth sub-stage in the conceptualisation stage utilises the Capability Opportunity Motivation Behaviour (COM-B) model (Michie, van Stralen and West, 2011; Michie, Atkins and West, 2014) to ascertain and understand how individuals' behaviour can be facilitated in moving them from their current unhealthy problem behaviour to their desired target behaviour. The third step in the conceptualisation sub-stage utilises the two theory- and evidence-based BCT taxonomies (Michie, et al., 2011; 2013) for identifying intervention components and ingredients (that is, BCTs) that are well-suited to the target behaviour (sub-stage one) and intervention options (sub-stage two) (Smith, et al., 2016).

After the first conceptualisation stage, Smith, et al.'s (2016) second stage combines Whittaker, et al.'s (2012) second and third steps into one stage, namely 'formative research and pretesting activities'. This stage aims to translate the mHealth intervention into a working app prototype for testing engagement, acceptance and use with a small sample of ±10 representative app users (for example 10 people) (Smith, et al., 2016). This approach to end user testing adopts the verified Health IT Usability Evaluation Model (Health-ITUEM) (Brown, et al., 2013), and also uses methods such as focus groups, semi-structured discussions and prototype feature walkthroughs with representative users (Smith, et al., 2016). These methods in Smith, et al.'s (2016) second stage align with the user-centred design approach for eliciting participant feedback (Poole, 2013; Yardley, et al., 2015a; 2015b; Schnall, et al., 2016; Faiola and Holden, 2017; Michie, et al., 2017). The third stage of Smith, et al.'s (2016) process, 'pilot trial', recruits a larger sample of ±30 research participants to refine the app prototype into a finalised app ready for larger evaluation trials. This final working app is then used in the last fourth stage, 'evaluation trials', which aims to test the potential of the complete mHealth intervention in terms of both objective quantitative efficiency and subjective-qualitative feedback measures. Smith, et al.'s (2016) approach to formative user testing and trial evaluations considers both the information systems and health behavioural sciences perspectives, respectively.

When utilising evaluation methods from both the health behavioural sciences and information systems perspectives, Murray, et al. (2016, p.14) suggests that larger scale RCTs be conducted after performing iterative prototype usability testing and only once the intervention is "stable"

in its form of delivery mode (such as a functional app). This allows for a high fidelity working prototype (or MVP) that can generate more meaningful findings from clinical simulated and real-life testing environments (Murray, et al., 2016).

In terms of strengths, Smith, et al.'s (2016) process addresses gaps in some existing processes that fail to incorporate evidence-based BCTs (such as the CeHRes Roadmap and CDE Framework) and theory- and evidence-based intervention ingredients (Glanz, Rimer and Viswanath, 2015; Stawarz and Cox, 2015; Kok, Peters and Ruiter, 2017; Michie, et al., 2017). Additionally, Smith, et al.'s (2016) process draws from and adopts verified and reliable theories and models from a variety of research domains including health behavioural psychology (the BCW, COM-B and BCT Taxonomy), usability (the Health-ITUEM), user-centred design (end-user testing and feedback elicitation), and health sciences (clinical RCTs). This represents a holistic and multidisciplinary approach to mHealth behaviour change intervention app development that draws from knowledge bases in both the health behavioural sciences and information systems worlds. This filters into another strength, which similar to other proposed works (van Gemert-Pijnen, et al., 2011; Poole, 2013; Bradbury, et al., 2014; Mohr, et al., 2014) acknowledges the importance of incorporating evaluation methods from both an information systems (usability and user-centred design) and health behavioural sciences (clinical trials) perspectives.

An arguable limitation of Smith, et al.'s (2016) process is that the mode of intervention delivery (such as a mobile app) is only considered in the third sub-stage (of the first conceptualisation stage) after the intervention has been designed. This is in contrast to Johnston, et al.'s (2015) contribution, for instance, which determines the mobile app platform and mode of intervention delivery from the initial outset, before the intervention is designed. Another noteworthy criticism of Smith, et al.'s (2016) process is that although acknowledgement is briefly given to the power of persuasion, this is done from a health behavioural sciences perspective, rather than an information systems perspective. Persuasion is simply acknowledged as a possible intervention option (in sub-stage two of stage one conceptualisation) which is viewed through a health behavioural sciences lens, and particularly through the theoretical BCW framework. Through an information systems lens, the power of persuasion holds alternative meaning; it is based on different assumptions, beliefs, ideas, theories and approaches. To clarify, from a health behavioural sciences perspective, persuasion is considered in terms of the intervention itself, whereas from an information systems perspective, persuasion is considered in terms of digital

and technological software design (Oinas-Kukkonen and Harjumaa, 2009; Kasali, et al., 2017; Langrial, et al., 2017).

### *A Holistic Approach to mHealth Intervention Design (Wang, et al. 2017)*

Wang, et al. (2017, p.1) proposes *A Holistic Approach to mHealth intervention design*, which amalgamates PSD with other existing theories, frameworks and models. Essentially, Wang, et al.'s (2017) Holistic Approach aims to bridge the gap between the use of evidence-based health behaviour theories (Glanz, Rimer and Viswanath, 2015; Michie, et al., 2016 ) and the user-centred design approach (van Gemert-Pijnen, et al., 2011; Johnston, et al., 2015; Mummah, et al., 2016; Schnall, et al., 2016; Smith, et al., 2016; Michie, et al., 2017). Bridging this gap is necessary to address the knowledge gap, advance the knowledge base and improve the practice of mHealth behaviour change intervention design, which includes mHealth physical activity apps.

Wang, et al.'s (2017) Holistic Approach is built on existing contributions categorised into three groups of theories, frameworks and models: (1) "behavioural theories" (including SCT, TTM, TPB, HBM and HAPA); (2) "technological models and frameworks" (including the BCT Taxonomy, PSD Model, BCSSs, JITAIs and the BIT Model); and (3) "user-centred design systematic approaches" (covering the CeHRes Roadmap, IDEAS Model and Wendel's Approach) (Wang, et al., 2017, p.1). Wang, et al. (2017) focus specifically on the smartphone intervention delivery platform and provides a demonstration of the Holistic Approach on a health promotion behaviour change smartphone app intended for reducing sedentary behaviour.

Wang, et al.'s (2017) Holistic Approach comprises several steps that cross over the three categories. The process starts with the "systematic approach" category, with step (1) understanding the human mind, the behaviour change, and the specific (health-related) problem, after which step (2) determines the target user group, target behaviour and behavioural outcomes. In performing steps (1) and (2) (under the "systematic approach" category), the designer makes use of the social-psychological theories of behaviour change (from the "behavioural theories" category). Step (3) (under the "systematic approach" category) then guides the design of the product or solution by drawing from five steps under the "technological model" category, by identifying the (3.1) aims, (3.2) behaviour change strategies, (3.3) elements, (3.4) characteristics, and (3.5) workflow. The five steps outlined in Wang, et al.'s (2017) "technological model" category utilise terms that are for the most part borrowed from

Mohr, et al.'s (2014) BIT Model. Steps (4) and (5) then adopt a rapid and iterative approach to evaluate and refine the design, respectively. In essence, Wang, et al.'s (2017) Holistic Approach integrates the application of "behavioural theories" and "technological models" into an information systems user-centred design process (that is, the "systematic approach"). Upon reviewing the Holistic Approach, a handful of strengths, limitations and critiques can be identified and discussed.

In terms of strengths, Wang, et al.'s (2017) Holistic Approach provides a comprehensive review of cognitive, behavioural and social psychological theories frequently covered in literature pertaining to health behaviour change literature, and mHealth smartphone intervention apps. These theories include SCT, the HBM, the TTM, the TPB, and the HAPA, which are all reviewed in Chapter 3 of the thesis's main body discussion. The use of evidence-based health behaviour change theories is similarly advocated for in other approaches discussed in this preliminary critical review, such as The BIT Model, The IDEAS Framework, The mHealth Intervention Development Process, as well as The Person-Based Approach. As for another strength, Wang, et al. (2017) also integrate the two credible, theory- and evidence-based BCT taxonomies (Michie, et al., 2011; 2013), which are also combined in other frameworks, models and approaches discussed in this review, such as The BIT Model, The IDEAS Framework, The mHealth Intervention Development Process, as well as The Person-Based Approach.. In addition, Wang, et al. (2017) emphasises the importance of multi- and interdisciplinary collaborative efforts and the sharing of expert knowledge between disciplines including behavioural sciences, human computer interaction (and user-centred design) and mobile computing.

In terms of limitations, Wang, et al.'s (2017, p.19) Holistic Approach offers structural guidance that is admittedly "a simplification" rather than a detailed in-depth methodological process, and the selection of behavioural theories is based on the authors' own literature retrieval rather than a formal systematic literature review process. Another limitation is that Wang, et al.'s (2017) review of existing theoretical models does not cover all of the facets of each model, but rather covers the theoretical aspects and constructs necessary for informing the development of their Holistic Approach.

Furthermore, while other holistic and multidisciplinary approaches incorporate the use of RCTs (such as The Digital Intervention Development Approach, The BIT Model, The CDE Framework, The mHealth Intervention Development and Evaluation Process, and The mHealth

Intervention Development Process), Wang, et al. (2017) exclude RCTs in their evaluation stage. They justify this by explaining that significantly more research is still required in terms of deciphering and establishing interdependencies between collaborative knowledge sharing on technology, human characteristics, the socioeconomic environment and the translation of health behavioural change theory into technical intervention elements, and essentially that "condition controlled experiments [are] less suitable for mHealth research" (Wang, et al., 2017, p.2). Wang, et al.'s (2017) justification stands ground in that advances in the mobile and smartphone app environment require rapid approaches to design, development and evaluation; methods that demand as little time as possible, yet are efficient and effective (Lathia, et al., 2013; Becker, et al., 2014; Jacobs and Graham, 2016; Nguyen and Poo, 2016). Their exclusion of RCTs, nevertheless, forfeits the generation of meaningful behavioural and clinical outcome findings that are necessary for determining the overall and long-term realised behavioural change effectiveness of interventions (Murray, et al., 2016). Murray, et al. (2016, p.9) explains that well-designed and rigorous RCTs remain an important part of evaluating digital mHealth behaviour change interventions, although they recognise that RCTs are "only one part" of a holistic approach to evaluation. Given the time constraints regarding mHealth behaviour change intervention app design, some researchers propose an isolated and tailored RCT evaluation method that focuses on assessing specific behaviour change intervention strategies and techniques (such as self-monitoring) embodied in the design of the app (Collins, Murphy and Strecher, 2007; Klasnja, Consolvo and Pratt, 2011; Jacobs and Graham, 2016; Klasnja, et al., 2017).

As far as other critiques are concerned, attention should be drawn to Wang, et al.'s (2017, p.1) Holistic Approach's second "technological models and frameworks" category, which falls under step (3) of the proposed process. Within this category, Wang, et al. (2017) suggest an unfamiliar grouping of "technological models and frameworks" in which they classify the BCT taxonomy, the PSDM, behaviour change support systems (BCSSs) and Just-In-Time Adaptive Interventions (JITAIs). A possible critique and concern for the research community, however, relates specifically to the consolidation of the BCT taxonomy with the PSD principles (from the PSDM). While the four models reviewed by Wang, et al. (2017) are all relevant and valuable for informing the multidisciplinary design of mHealth behaviour change intervention apps, Wang, et al. (2017, p.3) references the BCT taxonomy as a "technological model". In other words, Wang, et al.'s (2017, p.1) categorisation of the BCT taxonomy as a form of "technological model and framework" suggests that the BCT taxonomy assumes a

technological origin and information systems perspective. Wang, et al. (2017, p.2) further describes this "technological model and framework" category as relating to "technological frameworks for the implementation of mHealth interventions". Wang. et al.'s (2017) assumption, interpretation and classification of the BCT taxonomy under a "technological model and framework" category is mistaken and inaccurate. It is inaccurate because the BCT taxonomy originates from the health behavioural sciences perspective. More specifically, the BCT taxonomy was developed by researchers in the fields of "psychological theory", "health sciences research" and "health psychology" (Michie, et al., 2005, p.26; Michie, et al., 2011; 2013), and is largely concerned with informing the selection and reporting of BCTs (that is, the "intervention components" and ingredients constituting a complete health intervention) (Michie, Webb and Sniehotta, 2010, p.1897). Furthermore, while the BCT taxonomy is useful for informing the design, development and evaluation of BCTs in mHealth behaviour change intervention apps, the taxonomy is a highly generalised model, and can be used to inform the design of health behaviour change interventions delivered through other modes, platforms and means (Abraham and Michie, 2008; Michie, et al., 2011; 2013). For example, the BCT taxonomy has been used for informing interventions within face-to-face interactions, counselling sessions, educational and training settings, campaigns, written materials, discussion groups, peer-led laboratories, worksite and organisational procedures and protocols, and telephonic interventions (Abraham and Michie, 2008; Michie, et al., 2011; 2013; Samdal, et al., 2017).

On another note, Wang, et al. (2017, p.11, 12) refer to both the PSD Model (Oinas-Kukkonen and Harjumaa, 2009) and BCSSs Outcome/Change Matrix (Oinas-Kukkonen, 2013) as "taxonomies". The principal paper first introducing the PSDM, however, is repeatedly described by the authors as a "framework" that discusses a "process" (Oinas-Kukkonen and Harjumaa, 2009, p.485) for designing and evaluating persuasive systems, and for "describing what kind of content" and software features may be found in a persuasive system.

On the one hand, in terms of the BCT Taxonomy, a 'taxonomy' describes a theory- and evidence-based agreed-upon language of distinct BCT labels, definitions and examples that offers a reliable method for specifying, interpreting, implementing, evaluating and reporting the "active ingredients" (that is, intervention components) of behaviour change interventions. On the other hand, the PSDM offers a "conceptual framework" (Oinas-Kukkonen and Harjumaa, 2009, p.496) and "process model" (Oinas-Kukkonen and Harjumaa, 2009, p.486) comprising three phases for persuasive systems development. Wang, et al. (2017) justify their

classification of the PSDM as a taxonomy by stating that "[they] think the principles in the PSDM can serve as a taxonomy when designing mHealth interventions" (Wang, et al., 2017, p.12). They explain that the PSDM provides a comprehensive description for how technological software features can influence and persuade peoples' behaviours, and that there is a stable growth of evidence demonstrating the effectiveness of PSD principles in digital mHealth interventions, and particularly smartphone apps for mHealth promotion behaviour change intervention app design. Wang, et al. (2017, p.12) however exclude their justification for categorising the BCSSs Outcome/Change Matrix as a taxonomy, and simply explain it as a "strong contribution" that allows for a "more focused systematic review on PSDs". Despite incorrectly referring the PSDM and the PSD principles as a taxonomy, Wang, et al.'s (2017) classifying of the PSD principles as a "technological model and framework" is valid since it does originate from the information systems perspective (Oinas-Kukkonen and Harjumaa, 2009).

***The 26 Lenses for the Motivational Design of mHealth Apps (Geuens, et al. (2016)***

Prior to Wang, et al.'s (2017) Holistic Approach, Geuens, et al. (2016) published a combined and sorted catalogue of 26 design principles for specifically mHealth app design. Geuens, et al. (2016) refers to these 26 principles as *The 26 Lenses for the Motivational Design of mHealth Apps* (Geuens, et al., 2016, p.168). Geuens, et al.'s (2016) 26 Lenses for the Motivational Design of mHealth Apps was based on a review of the BCTs from the two BCT taxonomies (Michie, et al., 2011; 2013) and the 28 PSD principles from the PSDM (Oinas-Kukkonen and Harjumaa, 2009), and was also informed by Schell's (2008) *Book of Lenses* for motivational game design. Geuens, et al. (2016) categorised these 26 design principles into seven clusters based on similar underlying social psychological theories, namely: ability, information, awareness, gratification, social interaction, autonomy and credibility. Fundamental to Geuens, et al.'s (2016, p.165) knowledge contribution is that while "several frameworks and taxonomies" are available in literature, they are generic in nature and are not adapted specifically for the design of motivational mHealth apps. Geuens, et al. (2016, p.166) also report BCTs and PSD principles as "often described in an ambiguous manner" and are often described at different levels of specificity, granularity, emphasis, exhaustiveness and exclusively, which can result in "wrong interpretations and implementations" of these BCTs and PSD principles.

In accordance with other holistic multi- and interdisciplinary approaches (such as The Digital Intervention Development Approach, The BIT Model, The mHealth Intervention Development

and Evaluation Process, The IDEAS Framework, The CDE Framework, and The Holistic Approach), Geuens, et al. (2016) emphasise linking and integrating underlying social and behavioural psychology theories with BCTs and PSD principles. Geuens, et al. (2016) also emphasise that designers of mHealth behaviour change intervention apps need to be aware of the theories and constructs grounding the intervention designs they conceive and develop. Based on a review of design principles in mHealth apps, Geuens, et al. (2016) highlight difficulties that designers face when translating and operationalising BCTs and PSD principles into interactive user interface design features in mHealth apps.

In an effort to improve the pragmatic guidance offered to designers for designing mHealth apps, Geuens, et al. (2016) created an online tool. This online tool provides details regarding the (1) principles' names, definitions and small descriptions; (2) their underlying psychological theoretical construct drivers; (3) guiding questions and suggestions that designers and developers can ask themselves in clarifying ways in which they can operationalise and embed the design principles into the mHealth app's software features and functionalities; and (4) they provide examples in both text and illustrative screenshots of real implementations. Geuens, et al.'s (2016) online contribution to the knowledge base aims to address an issue highlighted by Dahlke, et al. (2015, p.1), who stress that "many of these apps appear to deliver health behaviour interventions but fail to consider design considerations based on human computer interface and health behaviour change theories".

Similarly to Wang, et al.'s (2017, p.2) Holistic Approach, which advocates for "researchers from both sides" to collaborate, Geuens, et al. (2016, p.166-167) stress that "both app designers and health [behavioural] researchers" need to work together in "consider[ing] all alternatives available" when it comes to advancing theory and design practices for mHealth behaviour change intervention apps. This reference to "all alternatives" is observed in their juxtaposing and merging of the BCT taxonomies (Michie, et al., 2011; 2013) from the health behavioural sciences perspective and the PSDM's PSD principles (Oinas-Kukkonen and Harjumaa, 2009) from the information systems perspective.

A limitation of Geuens, et al.'s (2016) review – similarly to Wang, et al.'s (2017) paper – is their failure to acknowledge and discuss the differing worldviews underlying the employed frameworks and taxonomies. However, unlike Wang, et al. (2017, p.3), Geuens, et al. (2016) does not attempt to categorise the BCT taxonomy as a "technological model", but rather explicitly recognises it as a "taxonomy" and not a framework or model, and recognises its

origins from the health behavioural sciences perspective. Therefore, Geuens, et al.'s (2016) 26 Lenses of Motivational Design for mHealth Apps respects the fields and perspectives from which the BCT taxonomies and PSD principles originate, and hence are able to offer a novel and valuable contribution to the growing holistic multi- and interdisciplinary approach knowledge base. To clarify, both Wang, et al. (2017) and Geuens, et al. (2016) offer knowledge contributions that aim to combine and integrate the BCT taxonomies with the PSD principles (from the PSDM), and both offer valuable insights for ongoing research. However, it is important in multi- and interdisciplinary collaborative work that each side's perspective (informed by different paradigmatic worldviews and interpretations of meaning) are respected in their own right, which Wang, et al.'s (2017) Holistic Approach does not explicitly do when classifying a BCT taxonomy as a "technological model and framework".

# Appendix G.1 (Chapter 6): Selection Criteria: Manual Selection Table

#### 6.3.2.3.4 Multi- and Interdisciplinary Approaches Selected for the Critical Thematic and Comparative Theoretical Analysis: Selection Criteria: Manual Selection Table

Several hermeneutic cycles were performed using the search strategies, reading and acquisition techniques, and the two selection and template criteria. Hundreds of publications were reviewed and considered over a ten-month period in 2019, ultimately yielding a preliminary sample of forty-five literature publications. A lack of detail provision (selection criteria, criterion #7, Table 6.4) and an insufficient meeting of the necessary boundary object view information and insights (template criteria, Table 6.5) led to the exclusion of nine literature publications. The remaining thirty-six literature publications were carefully read, re-read, analysed and compared against the selection criteria (Table 6.4) and template criteria (Table 6.5). Appendix G.1 and Appendix G.2 provide the manual matrices created for all thirty-six publications in terms of the selection criteria and template criteria, respectively. After meticulous review, and thoughtful consideration for the four perspective categories (Figure 6.4), twenty literature publications were selected for inclusion in the final secondary dataset.

# SELECTION CRITERIA

| APPROACH | Landscape HP + Prev. | Landscape Intra-Inter | Landscape HBCIs, PA | Te, Digital mH, Apps | Theoretical Underpinning | Approach Phase Acts | Approach CoPs/MD | BO View Themes | Template | Theory Demo't Guideline Appr. | EXTRA APPROACH CATEGORISING HELP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. HOLISTIC FW (WANG, 2019) | ✓ | ✓ | ✓ | DHIs mH ✓ | BehTheory Toolkit ✓ | ✓ | very superficial ✓ | BCTs, MOPs, Twitmore ✓ | ✓ | ✓ | → HBC in HCI - Trends (Wang, 2018) Applies Tutorial For developers |
| 2. PERSON-BASED (2015) APPROACH (YARDLEY) | HP + Disease Mgt ✓ | Broad. Socio-ecological ✓ | HBCI ✓ | Broad + PA Applied. Yes + No DHIs ✓ | ✓ | ✓ | ✓ | BCTs, elements qual. methods ✓ | ✓ | ✓ | For persons who will use interventions. Health Psych Disrup. Factors Person-centered ①dev process & ②guiding principles |
| 3. IDEAS FW (MUMMAH, 2016) | specificity & HBC mod. ✓ | ✓ | ✓ PA Applied. | DHIs ✓ mH eH | Essential components ✓ | ✓ | Calls 4 end team explicitly ✓ | BCTs, Mut. Target (Table 1) (Extra BCTs) ✓ | ✓ | Look up demo papers (Lee, 2018) | UCD, BSUED, Design Thinking, Yardley's F based, B Theory |
| 4. LENSES & MOTIVATIONAL DESIGN (GEURTS, 2016) | HP + Disease Mgt ✓ | ✓ | CA ✓ | mH ✓ | New 2019 paper ✓ | Tool ✗ | Not really. ✓ | ✓ | CA brainstorm ✓ | CA. ✓ | New Paper accepted June 2019 - Digital Lenses - Bridging HBC Theory + App Design |
| 5. mH INTERVENTION DESIGN PROCESS (SMITH, 2016) | ✓ | ✓ | HE ✓ | mH ✓ | ✓ | ✓ | mention, not expand ✗ | BCTs, BCW, COM-B, Nature ✓ | ✓ | HE ✓ | UCD, MITIEM, BCW, BCTs, Whittaker, COM-B |
| 6. DEV + EVAL PROCESS & mH INTER (WHITTAKER 2017) | ✓ | ✓ | ✓ | mH ✓ | ✓ | ✓ | ✗ | Not really. ✗ Methods. | ✓ | Look up demo papers ✓ | Target user involvement. |
| 7. HOLISTIC FW 2011 (VAN GEMERT-P 2011) | HP, Disease Mgt ✓ | Broader ✓ | Socio-ecological Medical Chang. eH ✓ | eH ✓ | Calls mention-dll theories (p 5) ✓ | ✓ | SHs, p 4, 7 p 8 p 13 ✓ only 4 MD | Bus. Modelling offered ✓ | ✓ | Not 4 mH/PA Apps (Support Tool) ✓ | PD, UCD, PD, HCD, PT, "eH Res, Theory + Dev, MD Approach" Co-Op Res Guide Book (VEP, 2018) |
| 8. CDC FW / APPROACH (JOHNSTON, 2015) | ✓ | ✓ | Clinical ✓ | mH ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | Clinical App mH ✓ | UCD, |
| 9. DIGITAL INTERVENTIONS DEV METHOD GUIDE (EDAGUERY, 2014) | ✓ | ✓ | ✓ | Digital Int. mH ✓ | ✓ | ✓ | Acknowledges ✓ | ✓ | ✓ | Not really ✓ | Methodological Guide 4 Beginners developing DHIs ∴ mentions methods (very few BCI) mainly |
| 10. BIT + BIT-TECH MODELS (MOHR, 2014) | ✓ | ✓ | ✓ | MyHeartPal DHI ✓ mH | ✓ | ✓ | ✓ | ✓ | ✓ | MyHeartPal PA ✓ | Not UCD |
| 11. INTERVENTION MAPPING APPROACH (FACHS, 2016) | ✓ HP | Socio-ecological ✓ | HP Broad ✓ | General ✓ can be Te | ✓ | ✓ | Acknowledges ✓ | ✓ | ✓ | Good Success ✓ | Systematic FW, Iterative x linear, comprehensive, Kok 2017 IM Strengths, Determinants, Parameters, Theory-App link. |
| 12 BIT MODEL + IM (CRUTZEN, 2014) | ? | ? | ? | ✓ | ✓ | overlaps gaps ✓ | ✗ | Informative ✓ | ✓ | ✗ | Combines strengths of BIT, BIT-Tech and IM (INFORMATIVE 4 MY WORK, but not an APPROACH itself) |
| 13. IM + BIT & PA + SB mH HBCI (DIRETTO, 2018) | HP ✓ | Intra-Inter ✓ Inter-personal focus | SApps ✓ mH PA | SApps ✓ mH | ✓ | ✓ | ✓ | Motivx ✓ | ✓ | Extended PA ✓ | BIT MODEL, IM, IM Taxonomy, Determinants, Theory Conceptual + Te Fwks interesting APP but v little (p.M) |
| 14 mH AGILE DEV + EVAL LIFECYCLE (WILSON, 2018) | HP, DM, Drugs CHI ✓ | CanBe ✓ adv or header | mH HP ✓ Broad. Pharm | mH ✓ | FW theories, not HBC Theory ✓ | ✓ | Calls 4 eHI involved P4 P2 ✓ | Methods few & design process ✓ | ✓ | Not really coping BCTs ✓ | Strengths in Agile Dev Methodology (Dynamic, rapid, iterative)(p2) Considerations (prioritising) Eff Good developer collab. (Agile + (SDev) Alpha/Beta testing. UCD, HCD, E-Res, UXD, Design Thinking |
| 15. mH APP INTERVENTION DEV PROCESS (CURTIS, 2015) | CHI, HP ✓ | Person-Child and Inter-Inter (Family) ✓ | HP WM HE ✓ | MH SApps ✓ | FW theories, not HBC Theory ✓ | ✓ | Calls 4 collab (esp w experts) in MB & WMHs ✓ | ✓ | ✓ | WM, HE ✓ | UCD, Theory + evidence-based, systematic, Iterative Considered symptom based / Comprehensive. |
| 16. mH USER CENTERED 2019 DEV PATHWAY (BITTNER, | Preventive Med Clinics ✓ | ✓ | MI ✓ | mH SApps ✓ | ✗ | ✓ | Says MD is vital. Identifies ✓ | ✓ | ✓ | MI ✓ | Considers value of existing SW. UCD. Iterative Maintenance Identifies persons clinic. pathway |
| 17. UC DIGITAL DEV PROCESS MODELS HIT (CHOKSHI, 2018) | Clinical ✓ | Broad + ✓ | Clinical ✓ | HIT ✓ "beyond mH + Apps" | Discipline approach Neuro, Nutrit ✓ | ✓ | ✓ | N.eeds 4 Geriatric collab MD. ✓ | ✓ | NDeg clinics ✓ | UCD, Design Thinking, Agile, Lean, Rapid Dev, Pragmatic Process Pushes on Innovation Very good identifying lack of BCTs. |
| 18. IM TAXONOMY OF BC METHODS (KOK, 2016) | General but based on IM is. ✓ HP | Acknowledges interpersonal HP, but also intra-inter. ✓ | HP Broad. HBC ✓ | General + Te ✓ | HBC theories Determinants & underlying models ✓ | Based on/ within IM ? = | ✗ | Is it still a valuable BO ✓ | ✓ | IM Taxonomy Supp Material Generic ✓ | Effectiveness of BC Methods by linking Theory-based Determinants ↔ Practical Application (like BCTs) into Parameters. Aimed 1 Intervention developer 2 use. |

↓ Compare to BIT Model + BIT-Tech (parameters, etc)

↳ IM Tax applied to PA SApps (Robertson, 2011)(Middelweerd, 2018, by Appendix 1, Active 2 Other App)

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# APPROACH

# SELECTION CRITERIA

| APPROACH | Landscape HP + Prev. | Landscape Intra-level | Landscape HBCIs, PA | Te, Digital, MH, Apps | Theoretical Underpinning | Approach Phases Acts | Approach CoPs / MD | BD View Themes | Template | Theory Bases + Guideline Apps. | EXTRA APPROACH CATEGORISING HELP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19. GSQuID + QUALITY INT DEV (WIGHT, 2015) | Public Health Prev + PM | Broader socio-ecological | PA on Broad Socio-ecol scale | Generic c, can be Te | calls 4 MRC Theory | ✓ | calls 4 attendee collab + MS ✓ x identify | Not really | ✓ | GBV eg. PA eg (Hickman 2017) ✓ | Pragmatic Guided 6 steps, complex socio-ecological levels - multi-comp + logical + evidence-based + effectiveness for PA + multi-comp + Linear progression Models, can return prior apt + researchers. |
| 20. DIGITAL HEALTH INT. 2019 INNOVATION CAMPMAP (BURKEL, | Clinical, Prev ✓ PH, PM | Socio-ecological Broad | Clinical ✓ | DHIs, Apps MH | Acknowledge, not always ✓ some of Hers | ✓ | calls Ar programmes MD other ✓ Mentors | Not really | ✓ | Hospital Process ✓ | Strong MD consultation + calls 4 MD collab + combination Acknowledges + includes HCD (Patient) but mainly practitioner + research + users |
| 21. BEHAVIOURAL SC - UNFOLDING UNDOING (BSUED) PROCESS UXD (MEEKER, 2014) | HP ✓ | Intra-Inter ✓ | PA, HBCIs ✓ | MH, Stapps ✓ | Employers Summary sheet ✓ | ✓ | ✓ | ✓ | ✓ | MI Apps. Later after eval ✓ King 2018 + 2016 | UXD, Mathematical frames (Leader SCT), UCD, Rapid, Heuristic, |
| 22. PAL - ECP PROCESS (JANOLS, 2017) | HP. ✓ | Specificity Inter transferability ✓ | PA, HBCIs ✓ | HBCSS ✓ | ✓ | ✓ | Identify not elaborate ✓ | ✓ | ✓ | PA Check later 2017 ✓ Principles | Interpersonal formative TE + PSD (PSDM, Fogg, MI Apps PSD bit) Co-design Participatory Action-based PD BCSSs method + instrument |
| 23. MODEL 4 MOTIVATIONAL MH DESIGN (3M) (GIUNTI, 2018) | Chronic Cardiac Sick - Mgt CHI ✓ | Inter-Inter ✓ | Breast Cancer NS ✓ | MH Stapps ✓ | BCW model (main PSD BCSSs 15) ✓ Combination lack of Model + comp | ✓ | Factors through out ✓ | ✓ | ✓ | MS, Beh (over very detailed ✓ | 3 MDs + "Designers" + UCD, combination + main instrument aligned 4 engagement BCSSs. PT PSDM, UXD. Complex + Requires lots of prerequisites + very detailed + informed |
| 24. CO-DESIGN OF PH INTERVENTIONS (THALCEW, 2018) | Self Mgt, MH, CHI, Eth Mod ✓ | Inter-Inter ✓ | HBCIs, SM Int. ✓ | CHI including MH Stapps ✓ | Cannot Mix HBCBook Co Design Models ✓ | ✓ | Factors through ✓ | Facilitate design or factors BCSs etc ✓ | ✓ | MH Mental Health JM. ✓ | UCD, UXD, Agile, Iterative, Co-Design, Maps aspect to stages of design model, Rapid |
| 25. INTEGRATIVE PARTICIPATORY APP + SH ENGAGE IN HBC (CARVALHO, 2017) | Clinical Medical ✓ | All levels ✓ | Quality Improv in HC service del. ✓ | Generic can be Te ✓ | Inter CHI, PH + MH ✓ | ✓ | Discuss on collab + aligned + Mark PD Co-Prods ✓ | Yes ✓ | Quite much ✓ | UTh in ED ✓ | Shared Understanding, PD Total emphasis on build + resources that include diff. pragmatic + philosophical perspectives, methods + tools Co Det, Co Dev, Co Implem. |
| 26. PARTICIPATORY CO DESIGN METHOD 4 mHBCIs (WEHEEL, 2019) | HP Beh Med ✓ NED Chronic | Community mult. settings, inter + connect ✓ | HBCIs Incl PA ✓ | MH ✓ | BCW, TDF. ✓ | Need re identify suggest ✓ | 1 sort through ✓ | ✓ | ✓ | Obesity PINA NEDS ✓ | Co-Des PD, Iterative Philosophy Co-Des ↔ Def ↔ RCTs ↔ RCT into RCT elements (Content Models) |
| 27. OPENSOURCE PH (MUNOZ, 2018) | HP SM ✓ | Broad. can be ✓ | Mental Health Mod DC ✓ | MH Stapps ✓ | Intervention theory Diffusion ✓ | ✓ | Vertical vs Horizontal ✓ | Not really ✗ | Information + innovation + vertical vs horizontal ✓ | Mental Health No paper demo. ✓ | Creativity + Innovation emphasis on Adaptability + Dynamism and Change (Rapid) + uncertainty, unpredictability of HBC. |
| 28. FW + CO-PRODUCTION 4 PHIs (MARCINI, 2017) | Public Health ✓ | Psychosocial community ✓ | Public Health ✓ | Generic ✗ | MRC Guidelines ✓ | 3 stages ✓ | Yes But a ✓ | Very little on DBCI Some on Practical Support ✓ | Not much. Nice on Adults + Pregnancy + Older ✓ | Drugs + Industry NC Theor ✗ Apps | Rapid Prototyping. Co Production. Transdis + MD. Iterative + Summative (re builds on). Pragmatic + Guidance. Emphasis on MRC. Action Research Appr (TAR) |
| 29. MD APP 2 CO-DES + DEV OF COMPLEX HI (O'BRIEN, 2016) | HP Prev ✓ WB Unspecified | Inter-Inter ✓ Tailorable + appropriate web | Public Health Mod HBC | Generic can be Inter web ✓ | MRC Guidelines Fidelity, Feas, Co-Des Techniques ✓ | ✓ | Facilitators Obs MHs Co-Des Trans ✓ | Nice Pro Appropriate ✓ | Technology mediated methods ✓ | Web ✓ HEMP (incl PA) ✓ | Systematic + Sequential Guidance-based + complex HIs. Frame MDSMS. Aim 2 integrate Sc evidence + expertise + SH in real-world NB How 2 integrate using Techniques |
| 30. CHRONIC DISEASE MH APP INT. DES FW (WILHIDE, 2016) | Chronic Disease Mgt X Reactive | Individual + boundaries ✓ | SM of chronic Dis Mgt ✓ | MH Apps ✓ | Few MRC Theory, Guidance + Best practices ✓ | Incorporate → Dimensions ✓ | Individ. SMEs, Clinical, Edu, UX, HC SMs. ✓ | Not really ✓ | Use main bases on concepts, more for elements + phases ✓ | T Chronic Disease MH Apps Diabetes ✓ | Waterfall = systematic + sequential Iterative. Fw 7 Domains + Design elements in elements + Apps features. |
| 31. MD APPROACH 4 DEV OF GAMIFIED MH APPS (EDWARDS, 2018) FW | HP Prev CHI ✓ | Individual ✓ | Smoking Cessation HBCI ✓ | MH Apps ✓ | MRC Guidance ✓ | ✓ | MD, Teams Stg 5 ✓ | Methods ✓ | ✓ | Smoking Cessation apps ✓ | Gamification + MD. Agile Iterative Quick. UCD. Evidence + theory-based + systematic guidance. |
| 32. FW 4 HBCI DEV + DECISION-MAKING GUIDANCE (ARMITAGE-SOARES, 2019) | HP Chronic Disease SM ✓ | Considers self-care + support + Individual ✓ | Complex HBCIs ✓ | General Non-Acquired ✓ | Based off existing FWs (MRC, PP etc) ✓ TDF | ✓ | HP + Health ✓ Yes | Optimal HBCI (p.6) ✓ | ✓ | PA + SB (P Small ✓ comp. level) | Rapid, Iterative, Iterative, MD, Integrated, Lots of methods, tools + methods to use @ diff. Steps at Broad Dev UCD (p.7) |
| 33. MD APPROACH 4 DEV PERS TE 4 HPBCIs (HENKEMANS, 2015) | HP, Prev, SM ✓ HBCI. | Inter-Inter ✓ Tailoring Personalisation | HP, HBCIs and PA ✓ | PT incl. ✓ | eH, mH, SMapps ✓ | 3 main (p.6) components + 2 sub-components ✓ | Explicitly MD ✓ | ✓ | ✓ | Simple eg. Individual Tailoring Variables ✓ | PT, Combines Intervention Info + Te side. Model + Micro persuasion levels + use case modelling (15) too. Explicitly discusses "consumer pie" via DBCI (p.6) Common Lenses (Glasgow) |
| 34. PARTICIPATORY FW 4 CO-CREATION OF PHIs (LEASK, 2019) | Public Health CHI ✓ | Inter + Inter ✓ Specialised Individual ✓ | PH ✓ | Generic Can be Te ✗ NOISSAT Used | PD FWs ✓ Tools | 4 Sections 5 Principles ✓ | Explicitly ✓ MD (p.5) | Lots of Co-creation methods, FWs, tools, tables ✓ | ✓ | SG + PA ✓ NO TECH | Co creation UCD Eds Systematic application of Participatory methodologies + Co creation + Evaluation literature + methods + Principles + Recommendations and QI 4 each. 4 common |
| 35. MAP-IT (MAEN, 2017) | NCP Prev HP ✓ | Socioecological Individ ✓ | HBCIs ✓ | Generic Can be Te ✗ | ISCW ✓ | → Steps ✓ | Cluster 4 MD Kom in Step 1 ✓ | Website ✓ | ✓ | PA ✓ Older Adults (65+) | Complex HBCIs (Theory driven) + evidence-based Program Theory Framework to inform Practice Tools eg. checklists, worksheets, forms (available) |
| 36. MULTIDISCIPLINARY DIGITAL SEMINARS 4 COLLAB DES OF HISs (SCANDURRA, 2018) | Clinical, Public Health, Medical HC ✓ | Community, wider + Educational ✓ | Public, Medical ✓ | Clinical, HC ✓ | HISs Broad Clinical, Med. ✓ | Existing theories, frameworks, methods ✓ | very detailed + eg. steps ✓ | Practitioner + management ✓ MDTS Method | Lots! Good. ✓ | Quite well-very helpful ✓ | Old @ Home care ✓ | MD Method 1 User Needs Analysis + Requirements Specification PD, UCD, CSCW Common ground (Iterative, Reflective, work practices paper + goes Appreciation eg paper even more abstract) by Svanaes 2008 + Kok |

# Appendix G.2 (Chapter 6): Template Criteria: Manual Template Table

#### 6.3.2.3.4 Multi- and Interdisciplinary Approaches Selected for the Critical Thematic and Comparative Theoretical Analysis: Selection Criteria: Manual Template Table

Several hermeneutic cycles were performed using the search strategies, reading and acquisition techniques, and the two selection and template criteria. Hundreds of publications were reviewed and considered over a ten-month period in 2019, ultimately yielding a preliminary sample of forty-five literature publications. A lack of detail provision (selection criteria, criterion #7, Table 6.4) and an insufficient meeting of the necessary boundary object view information and insights (template criteria, Table 6.5) led to the exclusion of nine literature publications. The remaining thirty-six literature publications were carefully read, re-read, analysed and compared against the selection criteria (Table 6.4) and template criteria (Table 6.5). Appendix G.1 and Appendix G.2 provide the manual matrices created for all thirty-six publications in terms of the selection criteria and template criteria, respectively. After meticulous review, and thoughtful consideration for the four perspective categories (Figure 6.4), twenty literature publications were selected for inclusion in the final secondary dataset.

| APPROACH | Tel / Digital | underly. theories | CoPs identified | KB + Barriers | paradigm | context | D-cmo App Eqs | D. process phases | Res. activities tasks | BCS. | Design artefact objects | Supp. BCS artefact | interpret flex. | plasticity | flexible | abstract vs Concrete | deps | diffs | novelties | Collab X2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. HOLISTIC FW (WANG, 2019) | ✓ | ✓ | ✓ | X | Mention not discuss ✓ | HP mod. lifecycle HSC ✓ | ✓ | ✓ | ✓ | PSDs BCTs BCT Clusters ✓ | ✓ | Wireflows ✓ | BCTs + PDs overlays ✓ exci | ✓ | ✓ | ✓ | ✓ | BCTs + PDs ✓ | X | X |
| 2. PERSON-BASED APPROACH (YARDLEY) | Digital Y + N ✓ | ✓ | N few ✓ | Not really ✓ | IS + UCD vs HF + HCI | appl. domain ✓ | ✓ | Rela to many ✓ | Real contexts + longer ✓ | Few methods BCTs | prototypes ✓ | Methods ✓ | "usability" ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | New guidance studies ✓ | ✓ |
| 3. IDEAS FW (MUHMMAD, 2016) | ✓ | ✓ | ✓ | X | Motivations MOIbeh ✓ | HBC mod. PA HE ✓ | egs in ✓ | ✓ | ✓ | Mo tools it BCTs ✓ | Prototypes ✓ HVP | Methods ✓ | X | ✓ | ✓ | ✓ | ✓ | Divergent thinking ✓ | Phase 4 demo ✓ | Collab dimensioning etc ✓ |
| 4. LENSES 4 MOTIVATIONAL DESIGN (GEURTS, 2015) | mH ✓ | Several ✓ | Not really ✓ | X | "Diff underpin eg's in (p. 5) ✓ | HBC ✓ CA | Look @ 2009 CA ✗ | Tool ✗ | Lacks guidance @ 2009 ✓ | PSDs, Spell, BCTs ✓ | Image 2015, p 15 ✓ | X | BCTs + PDs overlap ✓ talk | consider- ed only ✓ | CA ✓ | ✓ | X | BCTs + PDs ✓ found | X | X |
| 5. mH INTERVENTION DESIGN PROCESS (SMITH, 2016) | mH ✓ | ✓ | mentions HD, not specific X | X | X | HBC ✓ HE | HE ✓ | ✓ | ✓ | BCTs FW, COM-B, ✓ MRUEM | prototype ✓ | Methods ✗ | X | not explicitly seen X | HE ✓ | ✓ | Iterations ✓ | X | X | X |
| 6. DEV + EVAL PROCESS 4 mH INTERVENTIONS (WHITEHEAD 2016) | mH ✓ | ✓ | a few ✓ irrelevant | X | X | HBC ✓ | little said ✓ | ✓ | ✓ | X | X | Methods ECT ✓ | X | ✓ | ✓ | ✓ | X | X | X | X |
| 7. HOLISTIC FW eH (ELDERS) (VAN GEMERT-PIJNEN 2011) | eH ✓ | ✓ | Stds ✓ | Back ✓ | Alt multi- perspectives p. 8 ✓ | Nor mH PA ✓ | less A PA ✓ mH | ✓ Back | ✓ Back | Approaches 3 BCT ✓ High | Look Apps 2 ✓ Back | Look Apps 3 ✓ Back | ✓ | ✓ | ✓ | ✓ | Mentions ✓ | mentions ✓ | Iter ✓ | Calls ✓ A |
| 8. CDF FW / APPROACH (JOHNSTON, 2015) | mH ✓ | X | ✓ | X | X | Clinical ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Methods ✓ | X | ✓ | ✓ | ✓ | X | X | ✓ | X |
| 9. DIGITAL INTERVENTIONS DEV METHOD GUIDE (CRAGG, 2013) | Digital ✓ mH | ✓ | Multidisciplin ✓ | X | Mentions diff disciplines X | ✓ | Other studies referred to ✓ | ✓ | ✓ | ✓ BCTs | ✓ | Methods ✓ | X | ✓ | ✓ | ✓ | X | X | X | X explicit ✓ |
| 10. BIT + BIT-TECH MODELS (MOHR, 2016) | ✓ | ✓ | ✓ | X | Diff discipline ✓ | PA ✓ | Mythmatic ✓ PA | ✓ | ✓ | FWs, FBT, multi-level ✓ | ✓ | ✓ | Diff terms perspectives ✓ | ✓ | ✓ | ✓ | ✓ | ontologies ✓ p. 6. | X | Clear Caution ✓ PG |
| 11 INTERVENTION MAPPING (IM) APPROACH (EARTH, 2016) | Emerged Co-Tech ✓ | ✓ | Sp 1 ✓ | Mentions Guidance ✓ | X | HP focused ✓ | Lots of gaps ✓ | ✓ | ✓ | Tailoring FB Frameworks ✓ | Main yes Model Logic p. 21 | Methods Manual ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 12. BIT MODEL + IM (CRUTZEN, 2014) | ✓ | ✓ | X | X | X | ? | X | ✓ | ✓ | Informative ✓ | Overlaps types ✓ | ✓ | ✓ | parameters ? ✓ | ✓ | ✓ | steps blurs models ✓ | Diffs of models ✓ | X | ✓ |
| 13. IM + BIT 4 PA + SE mH HBCI (DIREITO, 2018) | ✓ | IBCM ✓ | ✓ | X | Diff Aims BST Dev ✓ | PA Supp mH ✓ | Perfect ✓ | ✓ | ✓ | BCTs, IM, IM Taxonomy use + How ✓ | Human Factors ✓ | Methods under eval Step ✓ | Diff aims ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | BIT FW help comm p 1 ✓ |
| 14 mH AGILE DEV + EVAL LIFECYCLE (WILSON, 2019) | mH ✓ | Few discuss, not HBC theory ✓ | Teams called PO SMs PSCom ✓ | X | Not explicit but considered ✓ | Process ✓ | X | ✓ | ✓ and Extra BCs flexible ✓ | ✓ | Storyboards wireframes use in Phase 2 ✓ | Methods A/B Testing Analytics ECTs ✓ | Not really Taking diff ✓ | ✓ | Cover with TF again ✓ | ✓ | ✓ | Testing ? Eval ✓ | ✓ | Agile Others ✓ |
| 15 mH APP INTERVENTION DEV. PROCESS (MARTIN, 2015) | mH ✓ | TOF, not BCW and HBC theory ✓ | Includes a few ✓ p 4 p 7 | The education ? ✓ | Basic explicit, what is Here is CBT stories ✓ | HE, MRM ✓ | ✓ | ✓ | ✓ | BCW, COM-B, BCTs ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Collab, Team Comm all value ✓ |
| 16. mH USER-CENTERED DEV PATHWAY (BIAGIANTI, 2017) | mH ✓ | X | Yes. Table p2 ✓ | X | Not explicit ✓ | MI PH ✓ | MI ✓ | Little detail ✓ | No details ✓ | X | Prototypes ✓ | Methods ✓ | ✓ | ✓ | ✓ | ✓ | X | X | Rapid Cycles ✓ | Collab. Team S Prototyp ✓ |
| 17 UC DIGITAL DEV PROCESS MODEL 4 INT (CHOE HI, 2014) | HIT ✓ (p 2) | Discipline Theory Fun not mine X | Coaching + Empowerment ✓ | Facilitators ✓ | Diff disciplines ✓ | Clinical HIT ✓ | X | Revised ✓ | Defaulted with BCs ✓ | Motivation (eg 4 each SHs | Mentioned lots ✓ | Methods Use Review ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Interactive examples ✓ | Emphasised ✓ Will Share (p 10) 4 |
| 18. IM TAXONOMY OF BC METHODS (KOK, 2016) | General co-based on IM ✓ | ✓ | Just Mfgrs + Experts X | X | X | HP focus. ✓ | In Tables Supp reduced. ✓ | Within IM ✓ | Within IM. ✓ | IM Taxony itself is a very adjustable BCTs ✓ | X | Checklists eg COREQT, TIDieR ✓ | Acknowl- edges (p 5) | ✓ | ✓ | ✓ | ✓ | Acknowledges diff. interp terms (p 5). ✓ | X | shared (p 10) 4 ✓ |

RECAP STAGE'S 3 BD COMPONENTS (2019) slides

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# TEMPLATE CRITERIA

| APPROACH | Te Digital | Underly. Theories | CoPs Identified | KBt Brokers | Paradigms | Context | Demo App Eqs | Designated Process Phases | Des. Activities Tasks | Bos | Design Artefact objects | Supp. BCT or others | Incorpor. Flexibility | Platform | Flexible | Abstract vs. Concrete | Deps. | Diffr. | Novel Hrs. | Collab Kz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19. GSQuID – QUALITY INT DEV. (WIGHT, 2015) | Generic can be Te ✓ | ✓ | Not really ✗✓ | ✗ | ✗ | PH, Prev ✓ | GBV. Multiple BCT and GBV = 4 PA | ✓ | ✓ | RCTs ✓ | Diagram p.3 ✓ | Steps, Qs, Guide and Steps ✓ | Study Steps identified in comments ✓ | ? | ✓ | ✓ | ✓ | ✓ | ✗ | Guide, 9 but no guide. How. ✗ |
| 20 DIGITAL HEALTH INT INNOVATION ECOSYSTEM (MEHRING, 2018) | DHIs ✓ | Gaps, Abstr x Access, Mobility ✓ | Yes look at Clinics ✓ + PH | Calls 4 engagement recommendations + guide (p.5) ✓ | Need capital and other ✓ | Clinical ✓ | Clinical ✗ | ✓ | ✓ | Hierarchy of Technologies ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Emphasis on Innovation Toolkit ✓ | Emphasis on PHD collab ✓ |
| 21. BEHAVIOURAL SCIENCE-INFORMED WEBMODEL (ESMED) FOR EARLY UKD (HELLER, 2014) | mH Apps ✓ | Summary Sheet ✓ | Identifies ✓ | ✗ | BSC, HC, Sch equivalent SpBC ✓ | PA, HP ✓ | PA SAPP Lister King 2017 ✓ | 2016 | ✓ | Prototypes King 2015 Yes | Methodology Framework into App Prototypes | Methods ✓ | Not really explicit ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 22. PAR + BCP PROCESS (JANG LS, 2017) | FIGSSS ✓ | SOT, FGM, FGH 30 Lit. prioritisation | AFew ✓ | ✗ | Not explicit ✓ | HP ✓ PA Med. HBC | PA. (Three Core Components) ✓ | ✓ | Table Checklist p3 ✓ | ✓ | Template prototypes ✗ | Methods ✓ | Workshops Core to Iterate ✓ | ✓ | ✓ | ✓ | Iterate ✓ | Iterate ✓ | ✗ | ✓ |
| 23. MODEL + MOTIVATIONAL DESIGN (SMD) (GIUNTI, 2014) | mH Stepps ✓ | Mental Health Bundle PSD BCSC ✓ Lots | Identified Nurse Lead ✓ | ✗ | FT, BSS, PM (Mod. Te) ✓ | MS. BC Chronic SM ✓ | Detailed MS Report (Lister) ✓ | 3 Clusters and rather than Steps ✓ | Steps within Components ✓ | Regression Equation ✓ | Working Tool Care process Narrative ✓ | Methods chosen in Steps ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Not comparing goals etc. (p.10) Mis-comparing ✓ | ✗ | Mentions lots of Chal, goals & Sh problems + Lit on therapies ✓ |
| 24. CO-DESIGN OF EH INTERVENTIONS (THAKKEN, 2018) | eH including mH Stepps ✓ | Co design Models ✓ | Identify throughout ✓ | Identified in Step ✓ Facilitators | All perspectives ✓ | SM MH ✓ | MH SM ✓ | ✓ | Steps objects in Steps ✓ | Prototypes Toolkit ✓ | Mentions Names from models ✓ | Methods ✓ | 2 "prepare" ✓ | ✓ | ✓ | "abstract" (p.2) ✓ | ✓ | Barriers, power, Robust (p.2) ✓ | Evidence (p.2) ✓ many (p.2) | co-design participants ✓ |
| 25 INTEGRATIVE MULTIPARTY APP & SH ENGAGEMENT IN THC FW) (CARVALHO 2017) | Generic Compare eH, mH & oH ✓ | Based on CBM ✓ | Identified but reluctant to UTI in ED | Keen to be facilitators ✓ | All disciplines + processes BS, HP, DS ✓ | UTI in ED ✓ | UTI in ED ✓ | 3 steps, main subsidiary tools ✓ | ✓ | Low cost to BCT Table 2 (p7) ✓ | Methods Table Techniques Table 1 (p4) ✓ | Tools in Steps Table 3 (p6) ✓ | Co-creation of prototypes ✓ | Recommend RCT (p.11) ✓ | ✓ | ✓ | Multiple deployments p.15 ✓ | Yes - Long Cycle p.13 ✓ | 4 ✓ | Shared Understanding "Collab" means Yes! Co ✓ |
| 26 PARTICIPATORY DESIGN METHOD & MHBCA (VERKUIJL, 2018) | MH ✓ | PD Group Aids Help Use | Identified throughout + Gp PP ✓ | Co Design Expertise ✓ | Environ theory + MP reading mind. ✓ | Pilot mod. HP Based ✓ | Objects PwA Cultural or Tailoring ✓ | ✓ | Steps human mobil ✓ | Prototypes Recipes ✓ | Symptom Story Pathway ✓ | Methods Explicit Cards ✓ | Diary Entries Reflections (p4) ✓ | ✓ | Specific to Context ✓ | Process as user needs ✓ | Lots of work Tools & group activities ✓ | Diff perspectives within Cultural Gp & BCT Reflection ✓ | Add processes ✓ | Co Design-Making Partnership Yes ✓ |
| 27. OPENSELFCARE FW (MUNOZ, 2016) | MH Stepps ✓ | Inspiration ✓ | Mentioned vs Hospitalised ✓ | Power Dropbox ✓ | Transcultural Power ✓ | Mental health ✓ | Not really ✓ | FW, Values Guidance ✓ | ✓ | Not really ~ | Not really ~ | Little Detail, no Mod ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ (p.12) | Emphasis on really done ✓ | Yes ✓ |
| 28. FW & CO MOD PROCESS OF PHI (MANKINEN, 2017) | Generic ✗ | Focused on mHC ✓ | Identified but relevant 2 mHC ✓ | Facilitators recommended ✓ | Diff perspectives (small, chg) ✓ (pH) | Positive Health Concepts Strengths ✗ | No Apps Coaching + ✗ Prompt | 3 stages ✓ | Methods within 3 stages ✓ | Not really ✗ | Not really ✗ | Mentioned within steps ✓ | Conceptual Multi Realities ✓ | ✓ | Based on work-flow interconnection ✗ | ✓ | Co-Prod ✓ | Diff perspectives between SHIs ✓ (p.12) | Competing points typical ✓ | SH Central Co-Prod ✓ |
| 29. MD APP 2 CO DES + DEV OF COMPLEX HIS (O'BRIEN, 2018) | Generic but applied to web ✓ | Co Design - Bridge - HBC ✓ | Identified Coalitions (p.6) ✓ | Facilitators Champions Barriers ✓ | Not explicit ✓ | LEAP web mod FA ✓ | LEAP web, mod, FA ✓ | 7 Steps ✓ | 6 activities in 6 stages ✓ | Development Design Requirements ✓ | Workflows, mapping, Story ✓ | Methods to the Tech ✓ | ✓ | ✓ | ✓ | ✓ | Start stages to engagement ✓ | Diff knowledge sequence ✓ | Implementation from close codes ✓ | Lots of d-m, many cancel ✓ |
| 30. CHRONIC DISEASE MH APP INT. DES. FW (WAHDE, 2016) | mHApps ✓ | Adopt HBC Theories + Guiding Principles ✓ | Identified Key all related SMEs ✓ | Not really ✓ | Service, HC, Clinical Staff ✓ | Commun Language Hyp ✗ | Dynamic Design Phases ✗ HC | 7 clusters ✓ | Elements in Steps ✓ | Inputs into Inputs ✓ | Not really ✗ | Not really ✗ | ✓ | Not really ✓ | ✓ | Key decision ✓ | Outputs to Inputs ✓ | Diff perspectives Gaps Multidisciplines ✓ | Implementation ✓ | Lots ✓ (p.8) MD Integration & collaboration ✓ |
| 31. MD APPROACH + DEV OF GAMIFIED MH APP (EDWARDS, 2018) | mHApps ✓ | mHC, Int Stand Human guidelines ✓ | Identified p.3 & 4 p.11 ✓ | Facilitate of MP Know Effic ✓ | Not explicit ✗ | HP, HBC, Smoking ✓ | Learning explanation ✓ | 7 Steps ✓ | Methods in 7 steps ✓ | BCTs, Supported elements ✓ | ✓ | Large Focus on FGs Screening ✓ | Not really explicit ✓ | ✓ | ✓ | ✓ | Not explicit ✓ | Not explicit ✓ | ✓ | MD, Clients Expert + Users ✓ |
| 32. FW + HCI DEV + DECISION MAKING GUIDANCE (ARMIJO-SOLIS, 2014) | all Extreme Digital HCI ✓ KH Just | TDF, IM, etc. HCI etc ✓ | p.3, p.5 ✓ | Facilitation ✓ | Diff development views ✓ | Chronic Pain PM HCI Hs' ✓ | Spirit PT PA ✓ | A-G (7) ✓ | Steps ✓ | Workflows Links to Comm Models ✓ | Goal Methods Specific ✓ | Methods ✓ | Not explicit ✓ | Not really ✓ | ✓ | ✓ | ✓ | Pilot views ✓ | Risks diff co-design Prev Hosp ✓ | CO-prod, Co-design, Consortium (PT) ✓ |
| 33. MD APPROACH + DEV TECH + HP BCIS (MENKEMAN, 2015) | PT tips ✓ mH, mHApps | SDT UCD IM Heuristics ✓ | Yes ✓ | ✓ | Yes (p.3) ✓ | Robust ✓ | Gap in Tables ✓ | ✓ | ✓ | BCTs Glossary ✓ | Scenarios - conventional pic (p6) ✓ | Methods in each component ✓ | Diff program Manuals/Steps + Book are Interactive ✓ | ✓ | ✓ | ✓ | Brain 2 worlds ✓ | Diff project Brain Specif + Cult ✓ | Interaction from (p.18) ✓ | Brain HSc, HCI, HSD, Psych, KEngineering ✓ |
| 34. PARTICIPATORY FW + CO CREATION OF PHIS (LEASK, 2019) | Generic Combine Artificial Intelligence ✗ | Methods + Fwk + PD + Co-Design ✓ | Spider web Groups ✓ (p.7) | Champions + power ✓ | Nec Tech ✓ | PA SB PH ✓ | PA SB ✓ | 4 Sessions 5 principles ✓ | Fwk + tools in each Session Principle ✓ | Toolkit + artefacts 2 main principles ✓ | Artefacts + Cards + Mind Co-creation ✓ | Methods PD Co-Creation ✗ | Capable by Cards ✓ | ✓ | ✓ | ✓ | Skills + Required + Brain Co-creation | Common + power + diff purposes ✓ | Mobile learning Wellbeing ✓ | Co-Creation Collab Engagement + Tailored Fwk + Know Tools ✓ |
| 35. MAP IT (HARRISON, 2017) | Generic Can find Te eg. ✗ | BCW ✓ IM BCIS ANGELO | Not really ✓ | Not explicit ✗ | Not explicit ✗ | HP ✓ | PA = Older Model ✓ | 5 Steps ✓ | Table ✓ | BCT overlaid on Website ✓ | ✓ | ✓ | Implement in existing Tools ✓ | Implem ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | Comm with Users & Me ✓ |
| 36. MULTIDISCIPLINARY THEMATIC SEMINARS & COLLAB DES OF HISs (SKANDPURKA, 2018) | HISs Clinical Med ✓ | PD CSCW UCD Evang Fwk Key Needs | CSCW Evang Yes. Many Refs ✓ | Facilitator + Barrier + Skills needed Challenges identified. ✓ HIS Specialist | CS - CSCW Socio-Te perspective ✓ | Clinical, medical, HC ✓ | Child Parent Case ✓ | Figure 1 in Scandpurka paper 2. ✓ | Table 1 - Author + detailed perspectives ✓ | Prototypes Use of BCTs ✓ | Yes in part + Workshops Sketching ✓ | Mainly workshops, FGs, Surveys ✓ | Remote Int Interpret ✓ | ✓ | ✓ | ✓ | Take making Working Together ✓ | Diff Brain skills, etc ✓ | Imaginative Thinking projects ✓ | Collab comm Coop work process. Yes! ✓ |

# Appendix H (Chapter 6): Critical Theoretical Analysis

## 6.4 Critical Theoretical Analysis of Multi- and Interdisciplinary Approaches: Tables A, B, C and D

The template criteria (Table 6.5) provides a lens for conducting the critical thematic and comparative theoretical analysis on the twenty selected multi- and interdisciplinary digital health intervention development approaches (Table 6.6) across the four perspective categories (Figure 6.4). The hybrid cognitive reasoning strategy, along with disciplined imagination, thought trials, sensory perceptions, cognitive sensemaking, creativity, plausibility judgements and trial-and-error imaginary (mental) experimentation, is applied to identify, critically analyse and organise themes and subthemes relevant to the proposed boundary object view and intended interdisciplinary framework artefact (Chapter 7).

To conduct the critical thematic and comparative theoretical analysis, the six-step process was applied (Table 6.3). To briefly describe the key aspects of the process, firstly, the twenty selected multi- and interdisciplinary approaches were carefully read and re-read, and colour-coded highlights and notes were made, to enhance the researcher's familiarity with each literature publication and approach contribution. Secondly, the researcher meticulously reviewed, summarised and critically analysed each multi- and interdisciplinary approach according to the nine criteria in the template (Table 6.5). Four detailed A3 tables spanning 75 pages, organised by perspective category (Tables A, B, C and D, respectively), were produced during this meticulous process (Appendix H). Thereafter (thirdly), the researcher deeply immersed themselves in Appendix H, and performed critical cross comparisons of all potential themes, subthemes and theme relationships for the approaches within each of the four categories. The findings were then written up and reported in Sections 6.4.1 to 6.4.4.

Sections 6.4.1 to 6.4.4 provide the critical thematic and comparative theoretical analysis findings on the multi- and interdisciplinary approaches. The findings are divided in accordance with the four categories, namely the *Health Sciences*, *Information Systems and Technology*, *Partnership*, and *Integrative* perspectives, respectively. The findings are presented and discussed in terms of seven main themes (seven sub-headings), based on the template criteria (Table 6.5). The seven main themes cover the: (1) *aims and contexts*; (2) *actors and community of practice members*; (3) *perspectives, underlying theories, models, tools and existing approaches*; (4) *nature of the approaches and process steps and activities*; (5) *any design artefacts, boundary objects and supporting methods employed at each process step*; (6) *knowledge boundary contributions*; and (7) *noteworthy limitations and lessons learned*.

# *TEMPLATE CRITERIA FOR CRITICALLY ANALYSING 20 MULTI- AND INTERDISCIPLINARY APPROACHES*

| Template Criterion | Description of Template Criteria | Main Aim of Template Criterion | Multi-Disciplinary Approaches Selected for Critical Theoretical Analysis |
|---|---|---|---|
| 1. **Multi/Inter disciplinary approach number and title** | The **approach number** (sorted 1 to 20 – Table 6.6) provides a quick reference for the researcher. The **approach title** succinctly labels the contribution and indicates its category (1 of 4), digital technology platform and health context. | Provide a quick and easy reference for the researcher when conducting the critical comparative and thematic analyses between approaches. | **<u>Health Sciences Perspective:</u>**<br>**Approach 1:** Intervention Mapping (IM) Approach for Health Promotion Programmes (Bartholomew Eldredge, et al., 2016)<br>*(Bartholomew, et al., 1998; Bartholomew, et al., 2011); (Simons, et al., 2018)*<br><br>**Approach 2:** Holistic Approach to eHealth Technology Development: The CeHRes Roadmap (van Gemert-Pijnen, et al., 2011)<br>*Online CeHRes Toolkit (van Gemert-Pijnen, et al., 2019)*<br><br>**Approach 3:** MRC Guidance for Developing, Evaluating and Implementing Complex Health Interventions (Craig, et al., 2008)<br><br>**Approach 4:** Six Steps for Quality Health Intervention Development (6SQuID) (Wight, et al., 2015)<br>*(Matthews, et al., 2017)*<br><br>**Approach 5:** Intervention Mapping and the Behavioural Intervention Technology Framework for Developing an mHealth Physical Activity and Sedentary Behaviour Change App (Direito, et al., 2018)<br>*Supplementary Material (Direito, et al., 2018)*<br><br>**<u>Information Systems / Technology Perspective:</u>**<br>**Approach 6:** Development and Evaluation Process for mHealth Interventions (Whittaker, et al., 2012)<br>*(Matthews, et al., 2017)*<br><br>**Approach 7:** The Behavioural Intervention Technology (BIT) Model for eHealth and mHealth Interventions (Mohr, et al., 2014)<br>*Supplementary Material (Mohr, et al., 2014)*<br><br>**Approach 8:** IDEAS (Integrate, DEsign, Assess and Share) Framework and Toolkit for Digital Health Behaviour Change Intervention Development (Mummah, et al., 2016)<br>*(Lee, et al., 2018)*<br><br>**Approach 9:** mHealth App Intervention Development Process (Curtis, Lahiri and Brown, 2015) |
| 2. **Title, author and year of literature publication** | The **literature publication's title** provides information on the nature, perspective(s), category and context of the multi-disciplinary approach. The **authors' names** and **the year of publication** offers a reference source. The year of publication also indicates how recent the contribution is and provides insight into where knowledge advancements currently stand in the emerging digital health behaviour change intervention arena. | Provides the researcher with the approach's source reference and year of publication in literature. | |
| 3. **Aim and summary of multi/inter disciplinary approach** | The **aim** provides insight into the **purpose, focus and intention of the multi-disciplinary approach**. The **summary** succinctly articulates the multi-disciplinary approach's **general scope, essence and core contributory themes**. | Supports quick cognitive recap and summary reference point for researcher when conducting critical comparisons and thematic analyses between approaches. Aims to identify common goals shared by heterogeneous parties. | |
| 4. **Actors and community of practice members** | Identifies the **boundary actors and community of practice members** included in the multi-disciplinary team. These team members/practitioners are involved with, participate in and contribute to both the multi-disciplinary process and the final digital intervention product outcome design. **Knowledge disciplines and fields of expertise** can also be identified, thereby indicting the **heterogeneous worldview perspectives**. **Team facilitators and boundary/knowledge brokers** responsible for mediating, sharing, translating, coordinating and managing the multi-disciplinary team members can also be identified. | The criterion is used to inform which boundary actors and community of practice members may be included in the proposed artefact's development (Chapter 7). | |

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| **5. Perspectives, underlying theories, models, tools and existing approaches** | **Identifies the perspectives, underlying theories, frameworks, models and tools employed in the approach's theoretical foundation**. This criterion also identifies whether a multi-disciplinary approach is based on or informed by any **existing approaches**. | Aims to identify which necessary and relevant perspectives, theories, frameworks, models and tools can contribute to and may be included in the proposed artefact (Chapter 7). | **Approach 10:** Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps (Geuens, et al., 2019)<br>*First Version (Geuens, et al., 2016); Online Lenses of Motivational Design for mHealth Toolkit (Geuens, et al., 2019)*<br><br>**Approach 11:** mHealth Intervention Design Process for Behaviour Change (Smith, et al., 2016)<br><br>**Approach 12:** Agile Development and Evaluation Approach for mHealth Apps (Wilson, et al., 2018)<br><br>**Partnership Perspective:**<br>**Approach 13:** The Person-Based Approach for Developing Digital Health Behaviour Change Interventions (Yardley, et al., 2015a)<br>*(Matthews, et al., 2017)*<br><br>**Approach 14:** Participatory Design Approach for Stakeholder Engagement in Quality Health Behaviour Change Intervention Development (Carvalho, Jun and Mitchell, 2017)<br><br>**Approach 15:** Co-Design Approach for Developing Tailored mHealth Behaviour Change Intervention Apps (Verbiest, et al., 2018)<br><br>**Approach 16:** Multi-Disciplinary Thematic Seminars as a Collaborative Design Method for Health Information Systems Development (Scandurra, Hägglund and Koch, 2008a)<br>*Two Case Applications (Scandurra, Hägglund and Koch, 2008b)*<br><br>**Integrative Perspective:**<br>**Approach 17:** Holistic Framework for Developing Digital Health Behaviour Change Interventions: TUDER (Wang, et al., 2019)<br>*First Version (Wang, et al., 2017); Supplementary Material for the TUDER integrative taxonomy (Wang, et al., 2019)*<br><br>**Approach 18:** Multi-Disciplinary Approach for the Agile Development of Gamified mHealth Behaviour Change Intervention Apps (Edwards, et al., 2018)<br><br>**Approach 19:** Multi-Disciplinary Approach for Developing Health Promotion Behaviour Change Intervention Persuasive Technology (Blanson Henkemans, et al., 2015)<br><br>**Approach 20:** Behavioural Science-Informed User Experience Design (BSUED) Process for mHealth Behaviour Change Intervention Apps (Hekler, et al., 2011)<br>*Supplementary Material (Hekler, et al., 2011); Case Applications (King, et al., 2013; 2016)* |
| **6. Components of the multi/ inter-disciplinary approach** | Identifies the **main components, themes and subthemes** of the multi-disciplinary approach. This includes the **main phases, stages or steps of the process**, and the **activities and tasks within the main** components. The **nature** of the components within the approach can also be identified (e.g. iterative vs linear nature). | The main components, themes and subthemes may inform the core phases/stages/steps, and nested activities and tasks, of the proposed artefact, respectively (Chapter 7). | |
| **7. Design artefacts, boundary objects and supporting methods** | Identifies the various collaborative (cross-disciplinary) **artefacts, design boundary objects and supporting methods** (e.g. collaborative methods) employed and utilised in the multi-disciplinary approach. Identify or ascertain (latent) details pertaining to the **three core characteristics of boundary objects**: (1) interpretive flexibility, (2) plasticity, and (3) structure of informatics and work practice or process needs and arrangements. | Artefacts, design boundary objects and supporting methods identified as valuable for multi-disciplinary collaboration, cooperation, coordination and communication may be included in the proposed artefact (Chapter 7). | |
| **8. Knowledge boundary contributions** | Identifies **themes and subthemes** relevant to the multi-disciplinary management of three progressively complex knowledge processes (**transfer, translation and transformation**) over three knowledge boundaries (**syntactic, semantic and pragmatic**). This criterion also identifies **differences, dependencies and novelties** in knowledge. The managing of novelties, multi-disciplinary team power dynamics and knowledge sacrifices can also be identified. | Knowledge boundary themes and subthemes, and the managing of knowledge and power between heterogeneous team members identified in the analysis may be incorporated in the proposed artefact's development (Chapter 7). | |
| **9. Limitations and lessons learned** | Identifies any noteworthy **limitations, gaps and/or weaknesses** of the multi-disciplinary approach. This criterion also identifies lessons learned from the case applications of the multi-disciplinary approach in relation to the physical activity behaviour change smartphone app context specifically. | Limitations, gaps and lessons learned can inform future research and artefact developments for constructing a multi-disciplinary approach for physical activity behaviour change app design (Chapter 7). | |

## *TABLE A: THEORETICAL ANALYSIS OF MULTI-DISCIPLINARY APPROACHES FROM A HEALTH SCIENCES PERSPECTIVE*

| Health Sciences Perspective | | |
|---|---|---|
| **Template Criterion** | **Approach #1** | **Approach #2** |
| 1. Multi/inter disciplinary approach number and title | **Approach #1:**<br>Intervention Mapping (IM) Approach for Health Promotion Programmes | **Approach #2:**<br>Holistic Approach to eHealth Technology Development: The CeHRes Roadmap |
| 2. Title, author and year of literature publication | Planning Health Promotion Programs: An Intervention Mapping Approach (Bartholomew Eldredge, et al., 2016) | A Holistic Framework to Improve the Uptake and Impact of eHealth Technologies (van Gemert-Pijnen, et al., 2011) |
| 3. Aim and summary of multi/inter disciplinary approach | The approach provides developers of health promotion interventions with a systematic framework for effective decision making over six steps. Each step comprises several tasks, which upon completion, results in artefacts for guiding the subsequent step. The final product outlines a theoretical, empirical and practical blueprint detailing components, themes and subthemes for the intervention's development. The IM Approach has been applied to different generic, technological and mHealth interventions contexts. | The approach provides multi-disciplinary developers with a participatory development process and practical guidelines for co-creating and coordinating the development, implementation and evaluation of eHealth technologies. It outlines five intertwined phases and connecting cycles, and artefact outputs for each phase. It is based on an analysis of sixteen eHealth frameworks, and integrates evidence-based models from persuasive technology, human-centred design, participatory development and business modelling. The approach provides valuable insights for the collaborative and shared co-production of eHealth technology products, and supports decision-making in eHealth development. |
| 4. Actors and community of practice members | • Broad integration of actors described as stakeholders and community participants, including project initiator, academic institutions, community organisations, public health professionals, media, government, third-party payers.<br>• Questions to guide recruitment of team participants (p.216).<br>• Team facilitation processes (communication, task functions, team building and maintenance) (p.219) and processes for team consensus (p.222). | • Multi-disciplinary participatory team of researchers and developers including: healthcare professionals, researchers, technicians, policy makers, designers, patients, field experts (with specialist knowledge), project managers, financial investors and payers, insurers, government officials, other decision-makers, potential end users.<br>• Highlights issues regarding lack of well-defined powers and responsibilities for team members' roles – lack of team management, coordination and communication negatively affects eHealth technology outcome. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Public Health; Systems Thinking Approach; Socioecological Approach; Participatory Approach; Health Psychology; User-Centred Design (aspects).<br>**Individual and interpersonal level theories:** SCT; SLT; IP; HBM; PMT; TRA; TPB; IBM; RAA; GST; TTM; Theories of Automatic Behaviour and Habits; PAPM; ATRP; ELM; SRT; SDT; Stigma and Discrimination Theories; DIT; SN;SS. | **Perspectives:** Health Promotion; Health Psychology; Public Health; Systems Thinking Approach; Persuasive Technology; Persuasive Systems Design; Human-Centred Design; Participatory Approach; Business Modelling; User-Centred Design (aspects).<br>**Individual and interpersonal level theories:** DIT.<br>**Theoretical basis:** review of 16 existing eHealth technology frameworks. |

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| | **Theoretical basis:** None.<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; Taxonomy of Behaviour Change Methods.<br>**Existing approaches:** None. | **Models and tools:** PSDM; FBM; CALO-RE Taxonomy; BCTT v1; Precede-Proceed Model.<br>**Existing approaches:** None. |
| 6. Components of the multi/ inter-disciplinary approach | **Intervention Mapping main steps:**<br>• Step 1: Logic Model of the Problem<br>• Step 2: Program Outcomes and Objectives – Logic Model of Change<br>• Step 3: Program Design<br>• Step 4: Program Production<br>• Step 5: Program Implementation Plan<br>• Step 6: Evaluation Plan<br>**Nature of approach steps:**<br>• Iterative; systematic; non-linear; cumulative; theory-based; evidence-based<br><br>**Step 1: Logic Model of the Problem**<br>• *Activities:* Establish participatory group; conduct needs assessment; describe intervention context; state program goals.<br>• Pathways of problem causation; risk model defining causes of health problem; understanding target population and context.<br><br>**Step 2: Program Outcomes and Objectives – Logic Model of Change**<br>• *Activities:* State expected behavioural outcomes; specify performance objectives for outcomes; select (evidence-based, importance ranked) behavioural change determinants for outcomes; construct change objective matrices; create logic model of change (mechanisms of change).<br>• Performance objectives: observable and actionable subsets of behaviour (sub-behavioural) that together lead to behavioural outcome(s); sequential specification guides change process.<br>• Change objectives: actionable changes to meet or maintain performance objectives.<br><br>**Step 3: Program Design**<br>• *Activities:* Generate program themes, components, scope and sequence; choose (match and select) theory- and evidence-based change methods to address program objectives; select or design practical strategy applications to deliver change methods.<br>• Conceptualise and design intervention (describe program theme and subthemes that connect to the appropriate behavioural change messages).<br>• Bridge theoretical methods and practical applications (while meeting parameters). | **The CeHRes Roadmap main phases:**<br>• Phase 1: Contextual Inquiry<br>• Phase 2: Value Specification<br>• Phase 3: Design<br>• Phase 4: Operationalisation<br>• Phase 5: Summative Evaluation<br>**Intertwined connecting cycles:**<br>• Four Formative Evaluation cycles operating between the five phases.<br>**Process artefacts:**<br>• User Requirements; Prototyping; Value Drivers; Business Model<br>**Nature of approach phases and components:**<br>• Iterative; systematic; theory-based; evidence-based; cumulative; non-linear; interdependent; intertwined; dynamic; continuous connecting cycles; reflexive; reflective.<br><br>**Phase 1: Contextual Inquiry**<br>• *Aim:* Understand prospective users and context; analyse strong and weak points of current care provision.<br>• *Sub-phases:* identify relevant stakeholders (with roles and tasks); stakeholder analysis; description of current situation.<br>• Understand current situation: contextual, social and technological problems and issues.<br><br>**Phase 2: Value Specification**<br>• *Aim:* Determine values deemed important by stakeholders; translate prospective users' needs and values into specific requirements.<br>• *Sub-phases:* identify values; prioritorise and categorise identified values; create business model and value map; translate business model and value map into specific requirements.<br>• Value specification: precise and scoped values the eHealth technology should offer; defines goals, sub-goals and stakeholders' responsibilities to reach values.<br>• Types of requirements: content; features; design; usability and user experience; functional and modality; service; organisational and work practice; data; hardware; software. |

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| | • Creative idea generation for formulating bridges.<br>• Tailoring, and cultural and context sensitivity.<br>• Intervention change method: theory-based technique to influence determinant (process for how change may occur), specify parameters.<br>• Application: operationalisation, translation and organisation of change method into practical strategy (fit to context).<br>• Parameters: conditions under which methods are shown to be effective as applications.<br><br>**Step 4: Program Production**<br>• *Activities:* Refine program structure and organisation; prepare plans for program materials; draft (objective and context) messages, materials and protocols; pre-test, refine and produce materials.<br>• Main focus: produce messages and materials to bring program design (steps 1 to 3) to life.<br>• Focus: appropriate translation (method to practical application within parameter).<br>• Focus: ensured context and target population fit.<br>• Creative thought and practice integration; design documentation.<br><br>**Step 5: Program Implementation Plan**<br>• Identify potential program users (adopters, implementers, maintainers); state outcomes and performance objectives for program use; construct change objective matrices for program use; design implementation interventions.<br>• Determinants, performance objectives and outcomes of program use (adoption, implementation and maintenance).<br><br>**Step 6: Evaluation Plan**<br>• *Activities:* Write effect and process evaluation questions; develop indicators and measures for assessment; specify evaluation design; complete evaluation plan.<br>• Focus: develop an appropriate plan to evaluate efficacy and effectiveness of intervention program, its implementation process and outcome effects. | **Phase 3: Design**<br>• *Aim:* Develop a prototypical version of the eHealth technology based on the user requirements; ensure cooperative participatory team design approach involving prospective users and stakeholders together.<br>• *Sub-phases:* develop low fidelity and high fidelity prototypes; conduct usability tests; add persuasive elements.<br>• Highly iterative, dynamic and multi-participatory collaborative phase<br>• Involves iteratively developing, testing and refining low and high fidelity prototypes over time (testing with users, experts and possibly other stakeholders)<br><br>**Phase 4: Operationalisation**<br>• *Aim:* Launch eHealth technology; marketing plans; employ implementation theories; organisational work procedures are put into practice.<br>• *Sub-phases:* create a plan; determine concrete activities<br>• Finalise business model canvas and develop practical strategies and guidelines for business model execution<br>• Action plan: describes how the eHealth technology will be rolled out in the context (contextual inquiry)<br><br>**Phase 5: Summative Evaluation**<br>• *Aim:* Evaluate eHealth technology and determine whether eHealth technology achieves value specification.<br>• *Sub-phases:* determine impact (outcomes, effects) of technology; analyse uptake (adoption, use) of eHealth technology<br>• Evaluate: stakeholders' perspectives; impact, outcomes and effects (clinical, business, health behavioural change); uptake, adoption and use; team design, development and evaluation process<br>• Compare evaluation results to predetermined eHealth objectives<br><br>**Intertwined four connecting cycles – Formative Evaluations:**<br>• *Aim:* ongoing evaluation and iterative improvement of eHealth technology, design and development process, and team management<br>• *Sub-phases:* check whether the outcomes of previous phases have been accounted for; include stakeholders' perspectives<br>• Important for: ensuring eHealth project remains on track, detect problems as early as possible, solve issues and address problems as soon as possible, ensure guaranteed relationship between technology, stakeholders and context. |

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| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main steps:**<br>• Step 1: PRECEED model to create Logic Model of the Problem (diagram).<br>• Step 1: Review findings from literature and empirical studies.<br>• Step 2: Logic Model of the Problem to guide creation of Logic Model of Change (diagram) and Change Objective Matrices (tables); evidence-based theories.<br>• Step 3: Logic Model of Change and Matrices to select change methods and strategy applications for designing the intervention components.<br>• Step 3: CALO-RE Taxonomy and BCT Taxonomy v1 for theory-linked behaviour change techniques (individual socioecological level); evidence-based theories.<br>• Step 4: Preliminary program plan and creative support materials from Step 3.<br>• Step 4: Creative techniques (e.g. brainstorming, free association, mind mapping, metaphorical thinking).<br>• Step 5: Program plan, design documentation, support materials, protocols, pre-testing documentation.<br>• Step 5: Implementation and uptake frameworks (e.g. RE-AIM Framework, Interactive Systems Framework).<br>• Step 6: Program plan and implementation plan.<br>• Step 6: Evaluation frameworks, methods and checklists (e.g. CONSORT-eHEALTH (particularised to mHealth interventions), RCTs, adapted RCTs).<br><br>**Artefacts produced at main steps:**<br>• Step 1:<br>o Description of health problem<br>o Logic Model of the Problem (diagram) – provides a graphical representation of the causal relations between health problems and their determinants<br>o Statement of program goals<br>• Step 2:<br>o Behavioural outcome statement<br>o List of performance objectives<br>o List of selected (evidenced) determinants<br>o Matrices of change objectives (performance objectives x determinants table)<br>o Logic Model of Change (diagram) – provides graphical representation of mechanisms of change (pathways between change objectives, determinants, performance objectives and behavioural outcomes)<br>• Step 3:<br>o Preliminary Program Plan – describes ideas for organising methods and strategy applications into an intervention program | **Artefacts utilised at main phases:**<br>• Phase 1: qualitative and quantitative methods (including interviews, surveys, questionnaires, workshops, field observations, personas, scenarios, focus groups, diary studies, data logs, scoping reviews, secondary data analyses and statistical analyses, think aloud, etc).<br>• Phase 1: Review findings from literature and empirical studies.<br>• Phase 2: Contextual inquiry informs general ideas for identifying value specifications, creating the value map and establishing the list of specific requirements.<br>• Phase 2: Business model canvas (as a template).<br>• Phase 3: Outputs of contextual inquiry and value. specification serves as blueprint for the design phase.<br>• Phase 3: Persuasive and behavioural techniques: PSDM, CALO-RE Taxonomy, BCTT v1<br>• Phase 4: First version of eHealth technology; business model; implementation theories (e.g. DIT).<br>• Phase 5: Evaluation methods, value specification and eHealth technology objectives, business model.<br>• Formative evaluation cycles: prior phase outcomes and lessons, current phase processes and lessons.<br><br>**Artefacts produced at main phases:**<br>• Phase 1:<br>o List of key stakeholders (visualised stakeholder map)<br>o Key stakeholder analysis summary (expertise, roles, tasks, decision-making power, legitimacy and rating)<br>o Description of current situation: context, problem and scope (with issues); rules, regulations, ethical issues; and technological considerations and concerns<br>o Target market description<br>o Target behaviour description and understanding<br>• Phase 2:<br>o List of value specifications of all stakeholders<br>o Prioritorise (conflicting, negotiated and ranked) values<br>o Value map (values the technology should address)<br>o Business model – provides rationale for how the team aims to create, deliver and capture values – includes |

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| | ○ Intervention Logic Model (diagram) – graphical representation of change methods and practical applications to influence change objectives (pathways between methods and practical applications and Logic Model of Change)<br>○ Determinant tables (performance objectives and change objectives x methods)<br>○ Method-application tables (identify method and theory, define method, describe parameters, give application examples)<br>○ Linkage tables (behavioural outcomes, determinants and change objectives, selected methods, strategic practical applications)<br>• Step 4:<br>○ Design documentation from planning team to production team (project prospectus, sets of matrices, flow diagrams, storyboards, screen maps, pilot testing)<br>○ Design documentation from production team to planning team (storyboards, sketches, screen mock-ups and maps, layouts, graphics)<br>○ Suitability assessment for materials rationale<br>○ Messages (objectives and context)<br>○ Documentation on team meeting structures, contracts for team communications, negotiations and consensus building<br>○ Pre-testing documentation (formative and summative evaluation)<br>• Step 5:<br>○ Outcome and performance objectives for program use (adoption, implementation and maintenance)<br>○ Matrices of change objectives for implementation (performance objectives for adoption, implementation and maintenance x determinants)<br>○ Materials: awareness promotion, implementation manual, support training for implementers<br>○ Implementation plan (intervention program, adoption, implementation and maintenance)<br>• Step 6:<br>○ List of evaluation stakeholders<br>○ Effect (outcome and impact) evaluation assessments (measuring efficacy and effectiveness)<br>○ Process evaluation assessments (context, reach, delivery, reception, fidelity performance)<br>○ Specifications of indicators and measures for effect and process evaluation assessments<br>○ Evaluation plan (evaluation questions, evaluation design, indicators and measures, study protocols, resources, reporting standards)<br>○ Final (theoretically-informed, practical and empirically-/evidence-based) blueprint product | costs and benefits – outlines how the team will operationalise, actualise and implement the technology<br>○ List of specific requirements – states what is required by the technology for it to provide added value; goals; scope<br>○ Blueprint – requirements prescribing design details<br>• Phase 3:<br>○ Low and high fidelity eHealth technology prototypes<br>○ Usability test results and analyses<br>○ First version of the eHealth technology product<br>• Phase 4:<br>○ Action plan for operationalisation (contextual inquiry, business model, stakeholder inputs, implementation theory, concrete implementation activities)<br>○ Support materials: training, education, financing, business, technical support and maintenance<br>• Phase 5:<br>○ eHealth technology impact (outcomes, effects) and uptake (adoption, use) evaluation results, lessons learned and insights<br>• Formative evaluation cycles:<br>○ Evaluation results reflexively feedback into the approach process phases and the eHealth technology product for ongoing improvement |
| 8. Knowledge boundary contribution | • Artefacts, design boundary objects and supporting methods discussed support knowledge transfer, translation and transformation over the three knowledge boundaries.<br>• Team documentation supports team facilitations and dynamics. | • Multi-disciplinary project management planning and documentation (facilitators, team member positions, values, roles, responsibilities, decision-making powers, logistical plans). |

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| 9. Limitations and lessons learned | • The approach is highly complex (in breadth and depth) and is heavily time and resource intensive. Novel unexperienced developers may feel overwhelmed and struggle to implement the approach in practice.<br>• Approach is generalised to all complex health intervention programs (ranging pharmaceutics, epilepsy, nursing, physical activity, etc).<br>• Approach only caters for technology as a delivery vehicle (platform) from step 3, and therefore fails to consider usability, user experience, adoption and overall use of technology-based components<br>• Lack of clarity on community members and participating actors – guidance is highly abstracted.<br>• Collective understanding of specialist health intervention program (that is, health science) knowledge is assumed – failing to consider the less developed health science knowledge of technology specialists.<br>• Knowledge transfer, translation and transformation between heterogeneous participating actors is assumed to be highly plastic, fluid, flexible and straightforward.<br>• Multi-disciplinary team for program design and development is permeable and malleable, requiring consistent revising and readdressing of team foundation contracts, protocols and guidelines. This also disrupts team culture development and growth throughout a whole program project from start to finish.<br>• Highly abstract approach – steps, activities and guidelines are generalisable across all application contexts. | • Approach is generalised to all complex health interventions contexts (nursing, healthcare, diabetes, etc) and eHealth technological platforms (EHRs, EMRs, websites, PHRs, smartphones, robotics, etc) – lacking platform-specific operationalisation guidance for intervention developers<br>• Broad health information and communication technology (eHealth) focus fails to account for the distinctions in platform characteristics, and the nuanced differences in software features across various digital platforms (e.g. smartphone apps vs websites).<br>• The approach is heavily time and resource intensive.<br>• The approach assumes heterogeneous participating team members to hold a clear collective and shared detailed understanding of health interventions, technology and business practice, and an assumed understanding of what PSD and BCTs are, and how to operationalise them effectively into software features in various technological platforms.<br>• Emphasis is made on the lack of multi-disciplinary team guidance for well-defined roles, responsibilities, team positioning and decision-making powers, yet no further guidance or details are provided.<br>• Knowledge transfer, translation and transformation between heterogeneous participating actors is assumed to be highly plastic, fluid, flexible and straightforward. |

## *TABLE A CONT.: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM A HEALTH SCIENCES PERSPECTIVE*

| Health Sciences Perspective | | | |
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| **Template Criterion** | **Approach #3** | **Approach #4** | **Approach #5** |
| 1. Multi/inter disciplinary approach number and title | **Approach #3:**<br>MRC Guidance for Developing, Evaluating and Implementing Complex Health Interventions | **Approach #4:**<br>Six Steps for Quality Health Intervention Development (6SQuID) | **Approach #5:**<br>Intervention Mapping and the Behavioural Intervention Technology Framework for Developing an mHealth Physical Activity and Sedentary Behaviour Change App |
| 2. Title, author and year of literature publication | Developing and Evaluating Complex Interventions: New Guidance (Craig, et al., 2008) | Six Steps for Quality Intervention Development (6SQuID) (Wight, et al., 2015) | Using the Intervention Mapping and Behavioural Intervention Technology Frameworks: Development of an mHealth Intervention for Physical Activity and Sedentary Behaviour Change (Direito, et al., 2018) |

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| 3. Aim and summary of multi/inter disciplinary approach | The approach guidelines outline an iterative, non-linear and non-cyclical process for developing, evaluating and implementing complex health interventions. It outlines four main stages (comprising three activities each) along with standard questions for guiding developers in recognising and adopting appropriate methods for each stage. The approach provides key themes, methods and modelling artefacts applicable for the development and evaluation of theoretically- and evidence-based health behaviour change interventions. | The approach offers a systematic and pragmatic six-step method for guiding the design of quality public health interventions. Steps provide questions and recommended artefacts for logical and practical intervention development. 6SQuID is applied to interventions for gender-based violence, but details themes applicable to a wider variety of health contexts, and has been used for guiding mHealth physical activity behaviour change app development. | The paper integrates the Intervention Mapping (IM) approach and the Behavioural Intervention Technology (BIT) model to develop an adaptive mHealth promotion smartphone app-based intervention aimed at physical activity and sedentary behaviour change intended for the dual intra-inter(primary) personal socioecological level. It outlines key themes and subthemes relevant to the theoretical- and evidence-based design of physical activity intervention apps. Together with supplementary material, the paper provides extensive detail on linking and operationalising physical activity health behaviour change theory to the smartphone app platform. |
| 4. Actors and community of practice members | • A heterogeneity of team member (stakeholder) involvement is touched on, and some references are made to actors including third party stakeholders, and research teams. The approach suggests both indirect and direct target population representative user involvement at various stages of the complex health intervention development process. | • Emphasis is given to the need for "interdisciplinary teams" of practitioners, researchers, policy makers, target population (intervention users).<br>• Active mutli-disciplinary stakeholder involvement is emphasised at each step of 6SQuID.<br>• Mention is made of team facilitators, although no further details are discussed. | • No explicit reference is made to the multi-disciplinary team involved in the design of the mHealth PA intervention app, although disciplines of team members include: smartphone app and mHealth app design and development; health science; health behaviour change intervention development; health psychology; computer science; health promotion; medical technology; epidemiology; exercise and sport science. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Public Health; Person-Centred Approach; Socioecological Approach; Health Psychology; Participatory Approach; User-Centred Design (aspects).<br>**Individual and interpersonal level theories:** Emphasised as vital to informing health behavioural intervention design and development, but are not identified or described in the paper. References are, however, made to other source citations, which discuss theories including: HBM, TRA, TPB, SCT, TTM, HAPA, ELM, PMT, GST, SRT, SIT, DIT, as well as theories for control, decision-making, effort-reward imbalance, and automatic behaviour and habit theories.<br>**Models and tools:** CALO-RE Taxonomy, BCTT v1, COM-B.<br>**Existing approaches:** 6SQuID (Approach #4). | **Perspectives:** Health Promotion; Public Health; Health Psychology; Socioecological Approach; Participatory Approach.<br>**Theoretical basis:** review of 5 existing public health intervention development approaches.<br>**Individual and interpersonal theories:** None are explicated stated in the paper, although consistent reference is made to the importance of selecting evidence-based health behaviour change theories and their integration in an intervention's design and development.<br>**Models and tools:** PRECEDE-PROCEED Model.<br>**Existing approaches:** Intervention Mapping (Approach #1) and MRC Guidance (Approach #3). | **Perspectives:** Health Promotion; Socioecological Approach, specifically targeting the individual and inter(primary)personal levels; Participatory Approach; mHealth and Digital Technology Perspective; Health Psychology; Systems Thinking Approach; Exercise and Sport Promotion Science; Lifestyle Modification and Chronic Disorders Management; User-Centred Design (aspects).<br>**Individual and interpersonal theories:** IBCM; IBCM; TPB; SCT; SRT; SDT; GST; SS.<br>**Models and tools:** Just-In-Time-Adaptive Interventions (JITAIs); CALO-RE Taxonomy; BCTT v1; Taxonomy of BC Methods.<br>**Existing approaches:** Intervention Mapping (Approach #1) and the Behavioural Intervention Technology (BIT) Model (Approach #7). |

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| 6. Components of the multi-inter-disciplinary approach | **MRC Guidance main process stages:**<br>• Stage 1: Development<br>• Stage 2: Feasibility/Piloting<br>• Stage 3: Evaluation<br>• Stage 4: Implementation<br>• Stages 1 to 4 shared element: Reporting<br>**Nature of approach stages:**<br>• Iterative; systematic; non-linear; non-cyclical; cumulative; theory-based; evidence-based<br><br>**Stage 1: Development**<br>• *Activities:* identify evidence base; identifying/ developing theory; modelling process and outcomes.<br>• Emphasis is placed on reviewing current literature to identify evidence-based theories and empirical intervention findings relevant to the health behavioural intervention context.<br>• Draw on existing theories and conduct primary supplementary studies if needs be (e.g. interviews with experts from relevant knowledge disciplines).<br>• Develop and map understandings of target behaviour, target group, outcomes, objectives, determinants, behavioural change techniques, change processes, indicators and measures.<br>• Suggests employing a formal development process within MCR Guidance Stage 1, such as 6SQuID.<br><br>**Stage 2: Feasibility/Piloting**<br>• *Activities:* testing procedures; estimating recruitment/retention; determining sample size<br>• Scale: small scale; prior to large-scale evaluation<br>• Emphasis on formulation of testing procedures and parameters (selecting subjects, appropriate sample sizes) applicable to the context setting. Aims to prevent feasibility and piloting trials being undermined by problems of recruitment, acceptability, compliance, retention and delivery. | **6SQuID main process steps:**<br>• Step 1: Define and understand the problem<br>• Step 2: Identify factors for change<br>• Step 3: Identify the change mechanism<br>• Step 4: Identify delivery of the change mechanism<br>• Step 5: Test and refine on small scale<br>• Step 6: Evidence of effectiveness<br>**Nature of approach steps:**<br>• Iterative; pragmatic; systematic; linear; cumulative; theory-based; evidence-based<br><br>**Step 1: Define and understand the problem**<br>• *Aim:* define and understand the problem and its causes.<br>• Stakeholders work together to define and clarify an understanding of the health problem, and its attributional causes. Identify proximal and distal influences, and causal pathways.<br>• Define target audience for health intervention.<br>• Eight questions guide developers in answering the nature and extent of the problem, its causes and contributing factors, and lifestyle consequences.<br><br>**Step 2: Identify factors for change**<br>• *Aim:* identify and clarify which causal or contextual factors and determinants are modifiable and malleable; that is, which determinants have the greatest scope for change and who would benefit most.<br>• Identify which proximal and distal factors can have the most influence on health behaviour change (that is, which determinants are evidence-based).<br>• Create a causal pathway model (diagram), and identify point (or points) of intervention entry.<br><br>**Step 3: Identify the change mechanism**<br>• *Aim:* identify and clarify how to bring about the health behaviour change; that is, deciding on the mechanisms of change. | **PA mHealth app development process:**<br>• Phase 1: Develop the Conceptual Framework using the Intervention Mapping (IM) Approach<br>  o IM Approach steps 1, 2 and 3<br>• Phase 2: Develop the Technological Framework using the Behavioural Intervention Technology (BIT) Model<br>  o BIT Model components 1, 2, 3 and 4<br>**Nature of approach phases and components:**<br>• Systematic; cumulative; theory-based; evidence-based<br><br>**Phase 1: Develop the Conceptual Framework using the Intervention Mapping (IM) Approach**<br>• *Main aim:* understand the influences on PA and use evidence-based literature and theory to select components for the PA intervention's design.<br>• *IM step 1: Conduct a needs assessment*<br>  o Corresponds to IM step 1: Logic Model of the Problem.<br>  o Conduct scoping literature review to identify determinants, effective BCTs (intervention strategies) and mechanisms of action (MoAs) of PA behaviour and behaviour change.<br>  o Aims to understand what needs to be targeted and what needs to change (determinants).<br>• *IM step 2: Specify goals and change objectives*<br>  o Corresponds to IM step 2: Program Outcomes and Objectives – Logic Model of Change.<br>  o Specify PA intervention goals from the needs assessment; and specify PA performance objectives for PA behavioural outcomes.<br>  o Create matrices of change objectives for PA<br>  o Aims to specify the intervention goals and the change objectives (how determinants can be affected/influenced) for PA.<br>  o Change objective: what needs to change on a particular PA behavioural determinant to achieve a specific PA performance objective. |

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| | • Methods: utilise a combination of quantitative and qualitative methods for piloting and refining the intervention's design and development<br><br>**Stage 3: Evaluation**<br>• *Activities:* assessing effectiveness; understanding change process; assessing cost-effectiveness<br>• Emphasis on choosing suitable clinical trial (RCT) evaluation methods appropriate for assessing the specific health behavioural intervention.<br>• Distinguish between primary and secondary trial outcomes; remain alert to any possible adverse evaluation trial study consequences.<br>• Understand and evaluate change process to identify mechanisms of significant (or ineffective or adverse) impact in relation to context setting.<br>• Experimental designs and random sampling; minimise or counter any possible biases.<br>• Ethical considerations and adherence.<br><br>**Stage 4: Implementation**<br>• *Activities:* dissemination; surveillance and monitoring; long-term follow up<br>• Plan for how intervention is delivered.<br>• Training and support materials.<br><br>**Reporting**<br>• Emphasises full reporting at each stage of the MRC guidance process. | • A program theory (logic model of change) is developed based on the identified most promising determinants (modifiable causal factors).<br>• Emphasis is given to basing the program theory on evidence-based behaviour change theories (e.g. SCT, TRA) and explicitly articulating theories.<br>• Caution is given to developing overly optimistic (non-evidence-based) change mechanisms; and questions are asked whether change mechanisms are sufficient to address the health problem.<br>• Program theory: the change process; conceptualisation of how change is brought about.<br>• Change mechanism: "active ingredient" essential to triggering the behavioural change process.<br><br>**Step 4: Identify delivery of the change mechanism**<br>• *Aim:* identify and clarify how the change mechanism will be delivered.<br>• Develop an implementation plan describing details for how change mechanisms will be delivered (via channels and platforms).<br>• Select a delivery channel suitable to the specific target audience and context.<br>• Identify conditions and resources for delivery, and minimise any potential risks and possible unintended adverse effects of implementation.<br><br>**Step 5: Test and refine on small scale**<br>• *Aim:* test, adapt and refine the health intervention on a small scale; formative evaluation.<br>• Conduct repeated feasibility and pilot testing for individual level interventions.<br>• Test for acceptability, optimum intervention content and technique inclusion, intervention structure and duration, delivery platform, training, how to maximise potential intervention reach.<br>• Incremental and fractional factorial testing.<br>• Iterative testing and refinements should aim to achieve "good enough" intervention design. | • *IM step 3: Select theory-informed methods and practical applications*<br>o Corresponds to IM step 3: Program Design.<br>o Identify and select appropriate theory- and evidence-based change methods (or BCTs) for influencing each of the PA determinants.<br>▪ Make sure to identify and meet parameters (conditions) of change methods.<br>▪ Select theoretical models suitable to the PA target population and PA intervention goals<br>o Translate methods into practical applications.<br>o Select and design practical strategy applications – appropriate to app platform.<br>o Link PA performance objectives to respective PA behavioural determinants and practical app feature applications (tabularise).<br>o Aims to create method-application tables (mapping the respective PA determinants with theoretical methods/BCTs; examples of PA BCT operationalisation/practical applications; and parameters/conditions for effectiveness).<br><br>**Phase 2: Develop the Technological Framework using the Behavioural Intervention Technology (BIT) Model**<br>• *Main aim:* translate and operationalise the intervention components (intervention methods/ BCTs and practical strategy applications) into technological features for a PA mHealth app.<br>• *Four components:* (1) "why"; (2) "how" (conceptual); (3) "what"; (4) "how" (technical); (5) "when".<br>• *"Why":* specify aims (1) clinical; (2) usage.<br>• *Workflow:*<br>o Aim: set of rules (algorithms) that determine when and under which conditions the BIT elements (intervention components) are displayed and delivered to app users over time.<br>o Workflow examples: user defined, frequency, conditions, tunnelling. |

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| | | **Step 6: Evidence of effectiveness**<br>• *Aim:* collect sufficient evidence of effectiveness to justify rigorous evaluation and implementation on a larger scale; summative evaluation.<br>• Establish evidence for positive short-term intervention effects, and minimised unintended effects (employing credible evaluation methods). | • Design and produce the intervention materials.<br>• *BIT-Tech component 1: Profiler*<br>o Aim: defines the individual (the app user) and transmits (sensory and user input) data to the intervention planner.<br>• *BIT-Tech component 2: Intervention planner*<br>o Aim: chooses the relevant intervention elements and respective characteristics.<br>• *BIT-Tech component 3: Intervention repository*<br>o Aim: storage database of intervention elements.<br>• *BIT-Tech component 4: User interface*<br>o Aim: delivers the intervention elements to the individual (the app user). |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main stages:**<br>• Stage 1: Supplementary empirical studies (focus groups, interviews, surveys, expert meetings, process study); findings from literature.<br>• Stage 1: Causal modelling (diagram) – graphical representations of intervention design and causal pathway; evidence-based theories.<br>• Stage 1: Models and taxonomies for intervention design (CALO-RE Taxonomy, BCTT v1, COM-B).<br>• Stage 2: MOST (Multiphase Optimisation Strategy) framework; factorial experiments.<br>• Stage 3: Clinical experimental designs (individual randomised trails, cluster randomised trials, stepped wedge designs, natural experiments).<br>• Stage 4: None are identified.<br>• Reporting: CONSORT.<br><br>**Artefacts produced at main stages:**<br>• The approach does not describe specific artefact outputs for each stage. | **Artefacts utilised at main steps:**<br>• Step 1: Needs assessment practical guidelines; findings from literature and empirical studies.<br>• Step 2: Proximal and distal factors identified in step 1 inform the causal model; literature findings on evidence-based determinants.<br>• Step 3: Evidence-based theories; determinants table from step 2.<br>• Step 4: Outputs of steps 1 to 3; risk and resource assessments.<br>• Step 5: Outputs of step 4; facilitators.<br>• Step 6: Utilise evaluation guidelines (e.g. MRC Guidance) and credible evaluation methods (RCTs, observations, surveys, focus groups, interviews).<br><br>**Artefacts produced at main steps:**<br>• Step 1: Problem definition; answers to the eight guiding questions.<br>• Step 2: Causal pathway model (diagram); factors/ determinants table (factor x modifiable evidence).<br>• Step 3: Change mechanisms table (modifiable factors/determinants x change mechanisms x sufficiency to address health problem)<br>• Step 4: Preliminary intervention design; implementation plan; risk and resource plan. | **Artefacts utilised at process phases:**<br>**Phase 1:**<br>• Step 1: Scoping review of literature and evidence-based empirical study findings for the needs assessment; WHO PA guidelines; individual and interpersonal PA behaviour determinants; CALO-RE Taxonomy; BCTT v1; Taxonomy of BC Methods.<br>• Step 2: Needs assessment to inform program goals and sub-goals (i.e. intervention primary aims to promote increases in PA and reductions in SB).<br>• Step 2: Constructs of IBCM, TPB and SDT to specify performance objectives; PA determinants (table); mechanisms of action (MoAs); CALO-RE Taxonomy; BCTT v1; Taxonomy of BC Methods.<br>• Step 3: Outputs from steps 1 and 2.<br>• Step 3: Reviews of literature, meta-analyses, content analyses and other PA mHealth app intervention studies are conducted to inform the selection of PA change methods and PA BCTs.<br>**Phase 2:**<br>• BIT components 1 to 4 and workflow: Outputs of phase 1 are translated and operationalised into BIT elements (components, features) and workflow (algorithms) for the PA mHealth app. |

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| | | • Step 5: Testing programme (detailing methods).<br>• Step 6: Evidence of intervention effectiveness. | • BIT element design and development support software (Adobe PhoneGap; MySQL).<br><br>**Artefacts produced at process phases:**<br>**Phase 1:**<br>• Step 1: Needs assessment (table); list of PA behavioural determinants (table); list of evidence-based PA BCTs (table).<br>• Step 2: Program goals and sub-goals (intervention primary aims); behavioural outcomes; performance objectives (5); individual and interpersonal theories and theoretical constructs; matrices of change objectives (performance objectives x determinants (and MoAs) table)<br>• Step 3: Method-application tables (map respective PA determinants with theoretical methods/BCTs, examples of BCT operationalisation/practical applications, and parameters/conditions for effectiveness)<br>**Phase 2:**<br>• PA mHealth intervention app design (descriptions and graphical representations of the PA mHealth intervention app's components translated and operationalised into BIT element app features). |
| 8. Knowledge boundary contribution | • Some of the artefacts discussed in the paper (such as methods) are plastic enough for local and joint use, yet the paper does not discuss any challenges or issues pertaining to knowledge boundaries. It does not acknowledge nor discuss ways in which heterogeneous team members can collaboratively and cooperatively work together during the development, evaluation and implementation stages. | • The paper fails to discuss differences or similarities in heterogeneous knowledge.<br>• The approach essentially aims to address the gap that "there is little practical guidance for researchers and practitioners for how best to develop … health interventions", and strongly emphasises an inter-disciplinary stakeholder team at each step of intervention design and development, yet fails to provide practical process guidance for collaboration and co-production. | • The approach discusses utilising existing approaches and artefacts (theories, models, taxonomies) to support communication between mHealth app developers and health behavioural scientists (intervention developers).<br>• The use of artefacts to "bring together expertise from [health] behavioural science and [smartphone app] developers" is explicitly articulated. Although the paper fails to discuss knowledge boundaries and how to coordinate respective PA app intervention team design tasks, and how to manage multi-disciplinary team collaborations and communications. |

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| 9. Limitations and lessons learned | • The paper fails to identify multi-disciplinary actors involved in the intervention development process.<br>• The approach is generalisable to all delivery channels, and as a result does not include considerations specific to the design, development and (formative and summative) evaluation of digitally-delivered health interventions.<br>• Emphasis is placed on choosing appropriate and applicable theories, techniques and methods, yet no selection process guidance is provided, making the approach challenging to apply for novel intervention developers.<br>• The approach is highly challenging for novel unexperienced intervention developers to implement in practice.<br>• The approach is time and resource intensive.<br>• Evaluation prioritises RCTs as the gold standard for intervention assessment and fails to account for evaluations of delivery channels (or platforms).<br>• While a heterogeneous integration of disciplinary knowledge is recognised, no acknowledgement or discussion is given to the managing of such knowledge boundaries.<br>• The mode (medium/platform) of intervention delivery is only considered as team members approach the evaluation stage, failing to consider how the mode influences/affects the intervention's design.<br>• The approach addresses complex health interventions that target all socioecological levels, although details pertaining to the individual and inter(primary)personal levels are relevant and informative. Reference for this is particularly made to the NICE Guidelines PH49 on health behaviour change for individual approaches. | • Stakeholders are only briefly identified.<br>• Emphasis is placed on establishing a consistent collaborative co-production approach to intervention design and development, although no practical guidance is offer as to how to operationalise this multi- or inter-disciplinary stakeholder involvement.<br>• The intervention's delivery channel or platform is only considered at step 4, just before implementation planning, rather than recognising that particular platforms influence how an intervention can/cannot be designed/developed.<br>• The approach covers all socioecological levels, although details on individual and inter(primary)personal levels are relevant.<br>• Emphasis is placed on forming an "inter-disciplinary team", although no discussion addresses the differences in knowledge held by contributing parties, nor is practical guidance offered as to how to manage the multi- or inter-disciplinary knowledge of a collaborating team.<br>• Minimal artefacts are mentioned at the various steps for supporting the collaborative co-production process. | • The approach partially adapts the IM's steps and activities. For example, by shifting the last activity in IM's first step "state program goals" to its applied second step ("specify goals and change objectives").<br>• Multi-disciplinary team member involvement in the PA mHealth app design and development process is implicit and not explicitly articulated or discussed.<br>• The paper fails to discuss knowledge boundaries, and an understanding of differences in disciplinary knowledge and intervention design/development contributions are implicitly assumed (not explicitly stated nor discussed).<br>• The approach provides valuable lessons for designing and developing a physical activity health behavioural change intervention delivered specifically for the smartphone app platform.<br>• Tables, figures and supplementary material provide valuable insights and details into theories, theoretical constructs, models, change methods, operationalisations/practical applications, BIT elements, app features, workflows particularised to the PA and smartphone app contexts.<br>• The PA mHealth intervention app's design is generalised and not particularised to any specific target populations (other than insufficiently active healthy adults).<br>• The participatory approach advocated for can be improved by involving user-centred design methods, and conducting target population interviews, focus groups, surveys, etc – to further enrich the PA intervention app's design. |

***TABLE B: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM AN INFORMATION SYSTEMS AND TECHNOLOGY PERSPECTIVE***

| Information Systems and Technology Perspective | | |
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| **Template Criterion** | **Approach #6** | **Approach #7** |
| 1. Multi/inter disciplinary approach number and title | **Approach #6:**<br>Development and Evaluation Process for mHealth Interventions | **Approach #7:**<br>The Behavioural Intervention Technology (BIT) Model for eHealth and mHealth Interventions |
| 2. Title, author and year of literature publication | A Development and Evaluation Process for mHealth Interventions: Examples from New Zealand (Whittaker, et al., 2012) | The Behavioural Intervention Technology Model: An Integrated Conceptual and Technological Framework for eHealth and mHealth Interventions (Mohr, et al., 2014) |
| 3. Aim and summary of multi/inter disciplinary approach | The approach outlines six steps for developing, pre-testing and evaluating mHealth interventions. Three cross-cutting themes underlie the process, including a focus on target audience involvement, an underpinning theoretical basis, and a focus on mobile platform implementation. The paper's case application provides insights on methods, questions and measures at each step of the process. The approach has been applied in different mHealth behaviour change app development contexts, including physical activity. | The model provides a conceptual framework for articulating and translating the relationships between intervention aims, elements, characteristics and workflow, and a technological framework (BIT-Tech) for operationalising and instantiating the conceptual framework for technical implementation. It offers guidance to multi-disciplinary intervention teams by bridging the different fields and perspectives of health behavioural intervention sciences, health psychology, technology, information systems design and software engineering. The BIT model outlines key themes and subthemes for physical activity app intervention development, and has been applied to different health behaviour change and smartphone app contexts. |
| 4. Actors and community of practice members | • Experts are central to guiding the development and evaluation process.<br>• Other stakeholders participate at various steps when necessary (mention is made of funders, mobile providers, wireless network companies and other interested third-party stakeholders)<br>• Participants – as representatives of the target population/audience – are emphasised from the initial outset, and participate at all six steps of the development and evaluation process. | • The approach aims to support knowledge translation between experts from different disciplinary backgrounds, including health psychology, health behavioural change intervention sciences; digital technology; system design and development; mobile and smartphone app design and development; behavioural intervention technology development; persuasive systems design; human factors engineering; software engineering; human computer interaction. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Socioecological Approach; Participatory Approach ("target population involvement"); User-Centred Design; Lifestyle Modification and Wellbeing Management; mHealth and Digital Technology Perspective.<br>**Individual and interpersonal theories:** Briefly mentions SCT; SLT; SE; SS theories.<br>**Theoretical basis:** "theoretical basis" as a cross-cutting theme.<br>**Models and tools:** None. | **Perspectives:** Health Promotion; Socioecological Approach (targets individual and interpersonal); Health Psychology; Health Behavioural Science; mHealth and Digital Technology Perspective; Lifestyle Modification and Wellbeing Management; Persuasive Technology; Persuasive Systems Design; Information Systems Design; Human-Computer Interaction; Software Engineering; Collaborative Approach (emphasising Translation Communication).<br>**Individual and interpersonal theories:** Individual and interpersonal level theories such as TPB; TRA; HBM; SCT; SLT; GST; SRT; TTM. The paper critiques existing |

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| | **Existing approaches:** Intervention Mapping (IM) (Approach #1). | theories for not being adapted to suit factors important for the digital health behavioural change intervention platform.<br>**Theoretical basis:** Reviews three theoretical models, incorporates strengths of each.<br>**Models and tools:** Ritterband Model; FBM; BCSSs; PSDM; Just-In-Time-Adaptive Interventions (JITAIs); TAM; CALO-RE Taxonomy; BCTT v1; UML Modelling; OO Modelling.<br>**Existing approaches:** Development and Evaluation Process for mHealth Interventions (Approach #6); the BIT Model (Approach #7); IDEAS (Approach #8). Only acknowledges approaches to compare and critique, not integrate. |
| 6. Components of the multi/ inter-disciplinary approach | **mHealth Intervention Development and Evaluation process steps:**<br>• Step 1: Conceptualisation<br>• Step 2: Formative Research<br>• Step 3: Pre-Testing<br>• Step 4: Pilot Study<br>• Step 5: Randomised Controlled Trials (RCTs)<br>• Step 6: Qualitative Follow-Up<br>**Process cross-cutting themes:**<br>• Theme 1: Target Population Involvement<br>• Theme 2: Theoretical Basis<br>• Theme 3: Implementation Focus<br>**Nature of approach steps:**<br>• Iterative; systematic; linear; cumulative; theory-based; evidence-based<br><br>**Step 1: Conceptualisation**<br>• *Team of experts:* decide on the theoretical basis; review literature for relevant evidence-based theories, change methods and practical translations; and plan the development process.<br>• *Aim:* based on expert knowledge and expertise, select the mHealth intervention's theoretical foundations, and conceptually translate theory into practical methods and techniques for the mHealth platform.<br>• Employ methods to support expert tasks, e.g. brainstorming, literature reviews, focus groups.<br>• Formal processes (such as IM) can be utilised to aid step completion.<br><br>**Step 2: Formative Research**<br>• *Purpose:* conduct research with representative participants of the intended target population. | **BIT Model main components:**<br>**Theoretical Level: Conceptual Framework**<br>• *Focus:* behavioural intervention on a theoretical and conceptual level<br>• Component 1: "Why": Intervention Aims<br>• Component 2: "How" (Conceptual): Behavioural Strategies<br>**Instantiation Level: Technological Framework**<br>• *Focus:* BIT-Tech Model translates the theoretical and conceptual behavioural intervention into technical instantiations<br>• Component 3: "What": BIT Elements<br>• Component 4: "How" (Technical): Characteristics<br>• Component 5: "When": Workflow<br>**Nature of approach components:**<br>• Iterative; cyclical; rapid cyclical; cumulative; theory-based; evidence-based<br><br>**Theoretical Component 1: "Why": Intervention Aims**<br>• *Intervention aims: (1) Clinical aims; and (2) Usage aims*<br>• Clinical: focuses on intervention effectiveness; aims to change behavioural outcomes; determinants, cognition, knowledge, skills and motivation (e.g. increase in physical activity, reduce caloric intake).<br>• Usage: focuses on technological tool (digital platform, mHealth app); aims to maintain user engagement with technology and specific intervention components/ digital features during the intervention delivery period (e.g. usability and user experience studies, usefulness, satisfaction).<br>• Optional to break down aims into sub-aims for clarifying intervention goal(s).<br><br>**Theoretical Component 2: "How" (Conceptual): Behavioural Intervention Strategies**<br>• Behavioural change intervention strategies (or BCTs): the methods used to achieve clinical and usage aims; grounded in behavioural theories and models (e.g. |

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| | • *Aim:* inform the development of the mHealth intervention's content, format, aspects of style and regimen; gather further evidence and theory.<br>• *Activities:* determine target group's mobile phone usage behaviour; determine contextual factors affecting mobile interactions and intervention use; determine target group's preferences for intervention change methods and techniques; determine evidence-based regimens and recommended behavioural guidelines (e.g. PA guidelines).<br>• Utilise methods such as interviews, focus groups, online surveys.<br>• Three suggested questions regarding target population.<br><br>**Step 3: Pre-Testing**<br>• *Purpose:* pre-test the proposed mHealth intervention's design with representative participant users of the intended target population.<br>• *First aim:* determine and pre-test acceptability of the proposed mHealth intervention's content, format, components, messages, features, style, regimen and language (proof-of-concept study).<br>• *Second aim:* improve and refine proposed intervention design based on pre-testing feedback.<br>• Utilise methods such as interviews, focus groups, online surveys.<br>• Three suggested questions concerning users' intervention preferences.<br><br>**Step 4: Pilot Study**<br>• *Aim:* test mHealth intervention's content, regimen and main components to obtain additional detailed feedback from participants, to inform further finalising improvements to the intervention in preparation for trial (RCT) testing.<br>• *Additional aim:* prepare and test processes for trial testing (e.g. recruitment, registration, data collection, technical considerations, etc.).<br>• Utilise small and nonrandomised pilot testing methods.<br>• Three suggested questions pertaining to intervention acceptability and baseline trial testing measures.<br><br>**Step 5: Randomised Controlled Trials (RCTs)**<br>• *Purpose:* conduct pragmatic (real world setting) RCTs to collect rigorous evidence of mHealth intervention effectiveness.<br>• *Measures for real world settings:* health-related outcomes; objective measures; mHealth intervention adoption, acceptance, adherence and usage (frequency, total); user satisfaction; adverse/unintended effects. | education, knowledge and awareness, goal setting, monitoring and tracking, feedback, motivation enhancement).<br>• Provide clear rationale for strategies selected from taxonomies and strategies.<br><br>**Instantiation Component 3: "What": BIT Elements**<br>• Map behaviour change strategies (or BCTs) to BIT elements.<br>• BIT element: operationalisation of intervention strategies (or BCTs) into distinct components or objects of a digital intervention with which the user interacts; features/components of a digital intervention that support a user's interactions with the behaviour change strategies, and supports their achieving of clinical and usage aims; actual technical instantiations of strategies (or techniques).<br>• Commonly used BIT elements:<br>o Information delivery (one-way content delivered to user when user initiates access; formats: text, video, audio, images, combination of media).<br>o Notifications (individual messages pushed to user; formats: texts, within app; emails).<br>o Logs (user-entered data collection; formats: free entry, selection menus, rating scale, photos, picture imagines; exercise log).<br>o Passive data collection (data collected without user effort, sensor technology, data collected and transferred from external devices (e.g. watch, pedometer) and collected via APIs and other available sources (e.g. weather data)).<br>o Messaging (links user with other individuals supporting intervention; formats: professionals, paraprofessionals, peers via social networks, peer app users, discussion boards, chats, forums).<br>o Reports (reflections and summaries of data collected by the BIT element that are provided back to the user; formats: calendar, thought record, exercise record, calorie count)<br>o Visualisations (subset of reports conveying information derived from previously collected data and assessments; aggregated across an individual user or across groups of users).<br>• Flexibility: one specific behaviour change strategy (or technique) can be targeted by more than one BIT element.<br><br>**Instantiation Component 4: "How" (Technical): Characteristics**<br>• Further defining/refining/operationalising of BIT elements across dimensions to better fit/suit (of relevance to) user and optimise BIT element effectiveness; takes users' interactions into account; improves user's comprehension, engagement and ability to complete intervention, tasks or BIT elements. |

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| | • Conduct comparative studies across separate intervention components/ techniques, theories and interactive design features.<br>• Utilise pragmatic RCTs as the main evaluation method.<br>• Recruitment issues for trial indicate real world adoption issues.<br><br>**Step 6: Qualitative Follow-Up**<br>• *Aim:* inform subsequent mHealth intervention improvements, and determine implementation issues and methods.<br>• Conduct follow-up questions with participants to ascertain further in-depth understandings of: user satisfaction; intervention use; favoured intervention components/techniques/features; feature/component interpretation; behavioural effects.<br>• Determine potential effects for scaling up once implemented.<br>• Follow-up feedback informs whether the underlying theoretical foundations of the mHealth intervention demonstrate consistent real world effects on participants'/users' health behaviours.<br>• Utilise methods such as interviews and online surveys.<br>• Six suggested questions regarding improvements and implementation.<br><br>**Theme 1: Target Population Involvement**<br>• Target audience involvement and continuous participant feedback throughout the development and testing steps enhances potential engagement, usefulness and usability of mHealth intervention.<br><br>**Theme 2: Theoretical Basis**<br>• Ensure integrity of the underlying behaviour change theory (theoretical basis) underlying the mHealth intervention's development.<br>• Remain flexible to adaptations of practical applications of theory, given target population and context settings.<br><br>**Theme 3: Implementation Focus**<br>• Focus on implementation from the start to ensure final mHealth intervention product is suited for intended target audience and context.<br>• Engage with funders, mobile providers, wireless network companies and potential target users from the initial outset – increasing the likelihood for successful implementation. | • Common characteristics:<br>o Medium (media employed; e.g. text, audio, video, image; utilise theory, e.g. media richness theory).<br>o Complexity (varies depending on user, target population and task; e.g. simplistic or detailed content; e.g. free entry, drop-down menus, barcode scanning).<br>o Aesthetics (varies depending on user's preferences, customisation settings and tastes; impacts user acceptance, experience, usability and continued use).<br>o Personalisation (the altering of characteristics or content of BITs to increase relevance for individual user; e.g. machine adaptive learning).<br><br>**Instantiation Component 5: "When": Workflow**<br>• Workflow: set of rules that determine when and under what conditions each BIT element (i.e. intervention component/strategy/technique) is delivered to an individual user over time; takes into account changes in aims, elements, and/or characteristics over course of intervention delivery.<br>o Common workflows: user defined (user decides sequence and timing); frequency (of intervention deployment); conditions (sets of rules; time-based rules, task-completion rules, event-based rules); tunnelling (uses data to determine which intervention components likely to meet user needs and preferences at a given time).<br><br>**BIT-Tech:**<br>• *Purpose:* instantiation of BIT design based on BIT Model into technological implementation guideline form for system designers and developers (e.g. mHealth app developers).<br>• *Aim:* shows the relationship among (1) software components developed for supporting BITs, (2) the user, and (3) the environment.<br>• *Notation:* technological translation of BIT Model concepts:<br>o intervention (I), aim (A), element (E), characteristics (C), workflow (W), data (D), time (t).<br>o Each intervention is a combination of an element and its characteristics: I=<E,C><br>• *BIT-Tech component 1: Profiler*<br>o Aim: defines the individual (the app user) and transmits (sensory and user input) data to the intervention planner.<br>• *BIT-Tech component 2: Intervention planner*<br>o Aim: chooses the relevant intervention elements and respective characteristics.<br>• *BIT-Tech component 3: Intervention repository*<br>o Aim: storage database of intervention elements.<br>• *BIT-Tech component 4: User interface*<br>o Aim: delivers the intervention elements to the individual (the app user). |

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| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main steps:**<br>• Step 1: Methods to support expert tasks, e.g. brainstorming, literature reviews, focus groups.<br>• Step 2: Methods for formative research with target population, e.g. interviews, focus groups, online surveys.<br>• Step 3: Methods for pre-testing, e.g. online surveys, focus groups, interviews.<br>• Step 4: Methods for pilot studies, e.g. small and non-randomised trials.<br>• Step 5: Utilise pragmatic RCT method<br>• Step 6: Methods for qualitative follow-up research, e.g. semi-structured interviews, and evaluation methods for assessing implementation impact: online surveys, telephonic surveys, semi-structured interviews.<br><br>**Artefacts produced at main stages:**<br>• Step 1: Expert-informed conceptualisation of mHealth intervention; team development and evaluation process plan.<br>• Step 2: Formative research results; intervention draft design(s).<br>• Step 3: Pre-testing target population/participant study results; final (pre-trial) intervention design (prototype).<br>• Step 4: Pilot study findings; preliminary RCT testing plans and measures.<br>• Step 5: Empirical RCT study results and findings.<br>• Step 6: Qualitative follow-up findings. | **Artefacts utilised at main components:**<br>• Component 1: expert knowledge; literature review and empirical study findings; treatment and intervention plans; recommended guidelines (e.g. WHO PA guidelines); TAM; usability heuristics; usability and user experience measures.<br>• Component 2: Behavioural change strategy toolboxes; CALO-RE Taxonomy; BCTT v1; evidence-based intervention strategies and change methods relevant to health behaviour and context; alignment specification between intervention strategies or techniques and clinical aims and usage aims; UML user state modelling (diagram).<br>• Component 3: evidence-based and case reviewed BIT elements; creative techniques; design generation.<br>• Component 4: Specification of BIT elements and designs.<br>• Component 5: Aims, BIT elements and characteristics; workflow understanding.<br>• BIT-Tech: Outputs of BIT Model to inform technological form for developers.<br>• Adapted RCT evaluation method for BITs: Trials of Intervention Principles (TIPs).<br><br>**Artefacts produced at main components:**<br>• Component 1: Health problem understanding; health behavioural change objectives; specifications of clinical aims and usage aims; aim-related theories.<br>• Component 2: User state model – UML diagram mapping past, current and future user states in relation to possible intervention treatments and aims.<br>• Component 3: Behaviour change strategies (BCTs) to BIT elements (map or table); Specification of BIT elements and designs; UML modelling of intervention design.<br>• Component 4: Description specifications of BIT elements and characteristics.<br>• Component 5: Workflow<br>• BIT-Tech: UML and architecture design modelling (diagrams).<br><br>**Boundary objects (repositories, objects and models, secondary objects):**<br>• Paper emphasises importance of and need for more ontologies (such as taxonomies) for further defining BIT elements, characteristics and workflows. An ontology provides multi-disciplinary teams with a formal language for creating conceptual maps, and facilitates rapid and automated BIT element construction. It can also facilitate interchanges of information across various actors (or systems) describing concepts, data and relationships and various levels of details, independent of particular names used in specific context applications. |
| 8. Knowledge boundary contribution | • Knowledge differences contributed by various heterogeneous participating actors remains implicit throughout the paper. While differences in expert knowledge are initially acknowledged in step 1 (conceptualisation), the paper fails to discuss multi-disciplinary collaborative team dynamics and cooperative/coordinated team work practices, and does not touch on the | • Paper discusses how experts from heterogeneous fields possess differences in knowledge backgrounds and expertise training, which informs different conceptual models for guiding health behaviour change intervention design and development.<br>• Argues for transfer, translation, transformation and integration of knowledge without ignoring relevant knowledge contributions from all contributing fields. |

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| | managing of knowledge processes, novelties, power or differences in disciplinary perspectives. | • The approach supports multi-disciplinary team members in explicitly articulating their intentions and domain-orientated goals into formalised models, specifications and diagrams. By formalising a process for making implicit intentions transparent, boundary-crossing communications and negotiations can be facilitated. Clear explicit communications also support the exchanging of ideas and the transforming of joint (shared) knowledge.<br>• Approach aims to translate knowledge and bridge links between theoretical, conceptual, instantiated and technological design/development. |
| 9. Limitations and lessons learned | • Heterogeneity in team member contributions is not discussed, although recognition is given to the need for multi-disciplinary actor involvement.<br>• The approach is time intensive – Whittaker, et al. (2012) describe the practical demonstrations of the proposed approach taking 3 to 4 years. This is unrealistic given the rapidly-evolving and quickly-advancing nature of the digital (technology), and particularly the mHealth application, environments.<br>• Intensive qualitative research studies at multiple process steps is time and resource demanding; fails to discuss knowledge boundaries.<br>• The approach holds value in its employment of various method use throughout, yet fails to mention other boundary objects and artefacts that can support and facilitate the mHealth intervention's iterative design, development and evaluation process.<br>• Design thinking techniques such as ideation, brainstorming, and rapid prototyping are not considered, and practical guidance is not provided for selecting behavioural strategies/components for intervention design. | • Although differences in fields, knowledge contributions and expertise are discussed, the paper does not provide guidance as to how artefacts or objects can support and facilitate the crossing of knowledge boundaries. It assumes knowledge transfer, translation and transformation to be a simple and easy task between heterogeneous collaborating and cooperating team members.<br>• The paper provides valuable insight into lessons applicable to both the mHealth platform and physical activity health behaviour change contexts.<br>• The approach fails to discuss facilitator involvement. Facilitators who operate at the boundary of knowledge translations are needed – actors who hold knowledge of related fields and are able to translate knowledge into different language (e.g. translating health intervention components/techniques into BIT elements, into mHealth app design features, into technological development notation).<br>• The approach does not incorporate user- or human-centred design processes, and fails to integrate information from users regarding usability and usefulness of BIT elements. |

## *TABLE B CONT.: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM AN INFORMATION SYSTEMS AND TECHNOLOGY PERSPECTIVE*

| Information Systems and Technology Perspective | | |
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| **Template Criterion** | **Approach #8** | **Approach #9** |
| 1. Multi/inter disciplinary approach number and title | **Approach #8:**<br>IDEAS (Integrate, DEsign, Assess and Share) Framework and Toolkit for Digital Health Behaviour Change Intervention Development | **Approach #9:**<br>mHealth App Intervention Development Process |

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| 2. Title, author and year of literature publication | IDEAS (Integrate, Design, Assess, and Share): A Framework and Toolkit of Strategies for the Development of More Effective Digital Interventions to Change Health Behaviour (Mummah, et al., 2016) | Targeting Parents of Childhood Weight Management: Development of a Theory-Based and User-Centred Healthy Eating App (Curtis, Lahiri and Brown, 2015) |
| 3. Aim and summary of multi/inter disciplinary approach | IDEAS provides a framework and toolkit for guiding multi-disciplinary teams in the design, development and evaluation of digital health behaviour change interventions. The framework outlines ten phases grouped into four stages. The paper identifies themes and artefacts at each phase for supporting collaborative multi-disciplinary engagement and development, and outlines pragmatic guidance for applying the framework. IDEAS has been applied to different health promotion behavioural change smartphone app contexts, and has been used in the physical activity context. | The approach outlines an iterative process for developing theoretical- and evidence-based mHealth behaviour change app interventions. It comprises ten steps, grouped into three stages, and identifies artefacts for collaborative intervention design and development. The paper discusses and applies key themes and subthemes relevant to the multi-disciplinary design, development and evaluation of physical activity behaviour change intervention apps. |
| 4. Actors and community of practice members | • The guidelines for applying IDEAS emphasises multi-disciplinary team engagement throughout the design, development and evaluation phases, arguing that "only a true multi-disciplinary team will have the knowledge and expertise to address the complex [aesthetic design, behavioural theory, evidence grounding, user-centredness, technical and rigorous evaluation] factors in tandem".<br>• Some multi-disciplinary actors identified include user-centred designers, programmers, behavioural science researchers, behavioural change intervention researchers, academics, engineers, and industry partners.<br>• Target user involvements and working with target population representatives (participants) are discussed at several phases. | • The approach emphasises the involvement of a multi-disciplinary mHealth app intervention design and development team, including health psychologists; target audience representative participants; health behavioural experts; researchers; mobile and smartphone app designers and developers; user-centred and user experience designers; software engineers; consultants from commercial mobile smartphone app companies; case workers; involved stakeholders (identified in the project's context-specific socioecological diagram); other stakeholders where necessary (such as financial, local authorities, community program managers, service commissioners).<br>• Calls for greater collaboration between health behaviour change experts and the commercial app industry to address gaps in the lack of evidence-based strategies in mHealth app interventions, the lack of theoretical content, and challenges regarding app user engagement. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; mHealth and Digital Technology Perspective; Systems Thinking Approach; Design Thinking; Human-Centred Design; User-Centred Design; User Interface Design; Lifestyle Modification and Wellbeing Management; Human-Computer Interaction; Software Engineering; Participatory Approach.<br>**Individual and interpersonal theories:** HBM; SCT; TTM.<br>**Theoretical basis:** reviews and incorporates several existing approaches and theoretical models to utilise "the best combination of approaches available"; Just-In-Time-Adaptive Interventions (JITAIs).<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; Health-ITUEM.<br>**Existing approaches:** The CeHRes Roadmap (Approach #2); MRC Guidance (Approach #3); Development and Evaluation Process for mHealth Interventions (Approach #6); Person-Based Approach (Approach #13); BSUED mHealth Apps Process (Approach #20). | **Perspectives:** Health Promotion; Socioecological Approach (community aspects); Health Psychology; Health Behavioural Sciences; mHealth and Digital Technology Perspective; Systems Thinking Approach; User-Centred Design; User Interface Design (latent); Lifestyle Modification and Wellbeing Management; Commercial (Smartphone) App Industry; Gamification; Human-Computer Interaction; Software Engineering; UML Modelling; Participatory Approach.<br>**Individual and interpersonal theories:** TPB; TRA; SIT; HBM; SCT; TTM; GST; SDT; SRT; SS.<br>**Theoretical basis:** review of existing approaches including Intervention Mapping (Approach #1) and MRC Guidance (Approach #3); Development and Evaluation Process for mHealth Interventions (Approach #6).<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; BCW; COM-B; TDF.<br>**Existing approaches:** Intervention Mapping (Approach #1); Reviews MRC Guidance (Approach #3); Development and Evaluation Process for mHealth Interventions (Approach #6). |

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| 6. Components of the multi/ inter-disciplinary approach | **IDEAS main stages and phases:**<br>• Stage 1: Integrate<br>  o Phase 1 (Empathise); Phase 2 (Specify); Phase 3 (Ground)<br>• Stage 2: Design<br>  o Phase 4 (Ideate); Phase 5 (Prototype); Phase 6 (Gather); Phase 7 (Build)<br>• Stage 3: Assess<br>  o Phase 8 (Pilot); Phase 9 (Evaluate)<br>• Stage 4: Share<br>  o Phase 10 (Share)<br>**Nature of approach stages and phases:**<br>• Iterative; flexible (phases can run in parallel, in combination or more than once); cyclical; rapid cyclical; systematic; cumulative; non-linear; theory-based; evidence-based<br><br>**Stage 1: Integrate**<br>• *Phase 1: Empathise with Target Users*<br>  o Engage all multi-disciplinary team members.<br>  o Identify and define broad health behavioural change intervention goal.<br>  o Conduct qualitative studies with the target population to better understand user needs and goals (employ qualitative methods).<br>  o Aim to extract unmet or latent user needs, values and motivations that can help inspire more innovative and creative mHealth intervention solutions.<br>• *Phase 2: Specify Target Behaviour*<br>  o Choose to target a specific health behaviour to serve as main behavioural change outcome (based on broad intervention goal); focus scope.<br>  o Examine susceptibility and countability of behavioural targets; investigate user preferences of mHealth intervention strategy delivery (e.g. framing behaviour as actions to increase rather than decrease).<br>  o Five guiding principles for selecting an intervention target behaviour.<br>• *Phase 3: Ground in Behavioural Theory*<br>  o Review and identify theory-driven behavioural strategies suited to both the target behaviour and digital platform medium (e.g. SCT; BCTT v1).<br>  o Use the IDEAS "Toolkit of Behavioural Strategies for Process Motivation" and literature to identify intrinsic process (and not only health outcome) motivators (e.g. choice, enjoyment, pride, challenge, competence, inherent satisfaction, fun, growth mindset, personalisation, identity, reframing).<br>  o Engage all multi-disciplinary team members in theory-driven insights process – prepare for subsequent brainstorming phase by exploring, discussing, comparing and reconciling the obtained theoretical insights. | **mHealth App Intervention Development main stages and steps:**<br>• Stage 1: Understanding the Problem and User Preferences<br>  o Step 1: Define the Problem<br>  o Step 2: Select the Target Behaviour<br>  o Step 3: Specify the Target Behaviour<br>  o Step 4.1: Understand the Problem<br>  o Step 4.2: Understand User Preferences for Technological Components<br>• Stage 2: Translating Research Findings into App Features<br>  o Step 5: Select User Preferences<br>  o Step 6: Select Intervention Functions<br>  o Step 7: Select BCTs<br>  o Step 8: Translate BCTs into App Features<br>• Stage 3: Pre-Testing and Refinement<br>  o Step 9: Piloting Potential App Features<br>  o Step 10: Refining App Features and Generating Content<br>**Nature of approach stages and steps:**<br>• Iterative; systematic; cyclical (feedback loops between stages); rapid cyclical; cumulative (between stages); linear (within stages); theory-based; evidence-based<br><br>**Stage 1: Understanding the Problem and User Preferences**<br>• *Purpose of stage 1:* conduct formative and literature research to identify theoretical, user-centred and app technological components that should be considered for the mHealth intervention's design and development.<br>• *Step 1: Define the Problem*<br>  o Review literature and empirical study findings to define the overall health problem in behavioural terms, and specify the context of focus.<br>  o Identify individuals, groups and populations involved with behaviour, and create a socioecological systems diagram, nesting the target audience in the centr.<br>• *Step 2: Select the Target Behaviour*<br>  o Consider all possible target behaviours, and select one or two specific behaviours to target (BCW suggests starting with small changes that can be built up incrementally over time).<br>  o Conduct focus groups and discussions with experts (or specialised health behavioural consultants) to ascertain optimum behaviour to target.<br>• *Step 3: Specify the Target Behaviour*<br>  o Based on the selection, specify the target behaviour and the context in which it occurs. |

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| | **Stage 2: Design**<br>• *Nature of stage:* highly iterative and rapid cyclical design process.<br>• *Focus of stage:* iterative refinement and improvement of idea generations regarding target behaviour, taking into account behavioural theory and users' feedback/insights throughout.<br>• *Phase 4: Ideate Creative Implementation Strategies*<br>o Conduct brainstorming idea generation sessions to ideate creative and innovative design solutions, based on target behaviour, users' insights; behavioural theory, and digital technology platform.<br>o Employ divergent thinking techniques and artefacts to facilitate multi-disciplinary team communication and joint idea generation sessions.<br>o Deferred judgement is important for team members to practice when generating inter-disciplinary creative ideas and innovative solutions.<br>• *Phase 5: Prototype Potential Products*<br>o Prototypes are developed to facilitate team discussions and further design idea generation sessions, and provide team members with an artefact for bridging (assisting) rapid cyclical iterations between phases 4 and 6.<br>o Prototypes should be developed and shared early on to enrich the collaborative creative idea generation/refinement, co-production process.<br>o Various prototype forms, generally initially low-fidelity and low-cost, and final prototypes are generally high-fidelity, detailed and more interactive.<br>o Prototyping techniques (e.g. parallel prototyping, sequential prototyping).<br>• *Phase 6: Gather User Feedback*<br>o Use various methods to gather and uncover target users' interests and feedback on prototypes and implementation strategies, including language use, aesthetics, potential barriers to using the mHealth app, and improvement suggestions.<br>• *Phases 4, 5 and 6:* conduct fluid and rapid iteration cycles in quick succession with prototypes; aim to improve concepts and refine the design solution.<br>• *Phase 7: Build a Minimum Viable Product (MVP)*<br>o Develop a fully functional MVP for (subsequent) pilot testing.<br>o Based on final prototype design, the MVP version(s) are developed to incorporate decisions regarding user experience, visual design, content, logical flow, trigger push notifications, graph and summary report calculations, analytics (dataset capturing patterns of usage), and metadata analytics (JITAIs, real-time data collection and tailoring).<br>o MVP version(s) should aim to build and test the mHealth app's primary intervention components, designs, and content delivery systems, and not yet incorporate unnecessary features. | o Create a target behaviour specification table, specifying who needs to perform the target behaviour, when, where, how often and with whom.<br>• *Step 4: Understanding the Target Behaviour and User Preferences*<br>o Conduct qualitative empirical research studies that explore both the health behavioural (COM-B; TDF) and mHealth app design (UCD) perspectives. Former explores facilitators and barriers to target behaviour; latter explores users' preferences of app design features.<br>• *Step 4.1: Understand the Target Behaviour*<br>o Conduct qualitative empirical research studies to create a COM-B Behavioural Diagnosis table (outlining COM-B; TDF themes; sub-themes; example supporting quotes from focus group studies).<br>o Create list of main COM-B and TDF related topics explored during focus group studies.<br>o COM-B Model: defines health behaviour as part of a system where three psychological domains interact to enable a behaviour: capability (psychological and/or physical); motivation (reflective and/or automatic) and opportunity (physical and/or social).<br>o TDF: comprises 14 theoretical domains drawn from a synthesis of 33 psychological theories and 128 key theoretical constructs relevant to health behavioural change<br>• *Step 4.2: Understand User Preferences for Technological Components*<br>o Conduct qualitative empirical research studies to identify ideas and preferences for app features and create an app feature preference table (outlining themes; sub-themes; example supporting quotes from focus group studies) (e.g. themes: app feature; time saving and convenience; aesthetics; gamification).<br>o Create list of app feature related topics explored in focus group studies.<br>o Consider diverse sample of commercial smartphone ownership and mobile operating systems (e.g. Android, Apple, Blackberry, Windows).<br><br>**Stage 2: Translating Research Findings into App Features**<br>• *Purpose of stage 2:* design a pre-test ready mHealth app intervention.<br>• *Step 5: Select User Preferences*<br>o Decide whether to "accept" or "reject" a selection of user preferences, ensuring balance with theoretical findings.<br>o Use a set of criteria to conduct the "accept/reject" decision process. Criteria examples: relevance to target behaviour; ease of implementation; alignment with usability and user experience recommendations; supported by theoretical findings and/or evidence. |

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| | o Manage practical challenges and decision-making process – weigh and balance different demands and priorities of multisector team members (e.g. balance influence of behavioural theory, user needs and desires, and technical, financial and practical feasibility); discourage incorporation of multiple, rather than isolated, behavioural strategies in MVP (a common assumption held by behavioural scientists and industry parties); resource constraints (human, financial, technical, time) and intervention specifications will influence how theory- and feature-rich an MVP is.<br>o Adhere to core tent of MVP: avoid wasting precious time and resources.<br>o Phase 7 may be conducted iteratively with other phases, particularly phase 6, to gather user feedback for informing MVP decisions before pilot testing.<br><br>**Stage 3: Assess**<br>• *Phase 8: Pilot Test (for Efficacy and Usability)*<br>o Pilot test MVP (using various pilot testing methods) to gather information on acceptability, usability, feasibility and potential efficacy of first viable version of mHealth intervention app.<br>o Test MVP to gain insight on preferred features, problematic or confusing user flows, opportunities for mHealth app feature design improvements and intervention (and/or specific component) modifications.<br>o Test and refine design and implementation procedures (recruitment, enrolment, retention, data collection) to avoid RCT evaluation problems.<br>o Randomisation may or may not be used at piloting stage.<br>o Pilot testing data informs further iterations of the MVP mHealth app intervention, in preparation for long-scale RCT evaluation.<br>• *Phase 9: Evaluate Efficacy in Randomised Control Trial (RCT)*<br>o Conduct a large-scale RCT to evaluate the efficacy and effectiveness of the mHealth intervention.<br>o Outcome efficacy and effectiveness measures include: target health behaviour; mediators, moderators, proximal behaviours, or conditions that lie on causal pathway to change behaviour; broader effects on health-related behaviours and risk factors.<br>o Important to consider the rapidly evolving nature of the digital mobile technology field throughout the RCT time duration, and continuously refine the mHealth intervention app to avoid it becoming obsolete by the time the rigorous trial evaluation process is complete (balance novel considerations with maintaining internal intervention validity).<br>o Make use of recommended RCT best practice evidence-based guidelines.<br>o Produce a refined final mHealth app intervention based on RCT evaluation. | o Consult with commercial mobile smartphone app companies to gain insight into feasibility of user preferences with regards to implementation (e.g. development and coding time, costs).<br>o Create an "Accept/Reject" Decision table (outlining main theme; user preference; accept/reject decision; reasons for decision)<br>• *Step 6: Select Intervention Functions*<br>o Based on the COM-B Behavioural Diagnosis table (output from step 4.1), use the BCW to guide the selection of which types of interventions (i.e. intervention functions) are likely to bring about change in the COM-B components and the associated TDF domains.<br>o Create a Theory and Intervention Function Component map (table) (outlining Com-B; TDF; sub-themes; intervention functions; examples).<br>o BCW: nine intervention functions that are likely to be effective in changing a specific target behaviour (e.g. education, persuasion, modelling, incentivisation, coercion, training, restriction, environmental restructuring, enablement).<br>• *Step 7: Select BCTs*<br>o Delineate selected intervention functions into BCTs.<br>o Review literature and empirical study functions to identify evidence-based BCTs in relation to the target behaviour, target population and context.<br>o Create a Theory-Intervention Function-BCT map (table) (outlining COM-B; TDF; intervention functions; BCTs).<br>o Have health psychologists review and verify the selection map (table).<br>o BCT: an observable, replicable and irreducible 'active ingredient' or 'mechanism of change' in an intervention that directly targets and brings about health behaviour change (an intervention strategy or component).<br>o PA BCT examples: self-monitoring; role modelling; goal setting; instruction.<br>• *Step 8: Translate BCTs into App Features*<br>o Use the App Feature Preference table (output from step 4.2) and Theory-Intervention Function-BCT map table (output from step 7) to translate the selected BCTs into potential app design features (informed by the user preferences study findings).<br>o Create a BCT-UCD App Translation table (outlining BCTs; gamification techniques; app features).<br>o Consult and liaise with commercial app company consultants when deciding how to implement BCTs into app features; consider user preferences during the consulting and liaising process.<br>o Integrate elements of gamification (e.g. achievement badges, trophies) and create a gamification (and BCT) technique list. |

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| | **Stage 4: Share**<br>• *Phase 10: Share Widely*<br>o Publish lessons learned and findings to both researchers and industry developers (scientific journals, conferences) to help bridge academic-industry divides, and advance the multi-disciplinary field.<br>o Publish findings in relation to existing theory, models and taxonomies (e.g. using standardised language and descriptors from CALO-RE and BCTT v1).<br>o Disseminate efficacious interventions more broadly with appropriate target audiences/populations.<br>o Consider disseminating the mHealth intervention via consumer app stores.<br>o Consider forming strategic partnerships to support ongoing improvements and reach of final mHealth app intervention. | o Consult and liaise with software engineers to develop (sequenced UML) flow charts on the (1) user's journey and (2) intervention delivery, where the intervention's BCTs and gamification techniques are linked to the specific app features.<br>o Have designers from the commercial app company develop interactive graphical mock-ups of the mHealth app to pilot test the proposed app features with some target user representatives.<br><br>**Stage 3: Pre-Testing and Refinement**<br>• *Purpose of stage 3:* pilot test and refine the mHealth app intervention's design.<br>• *Step 9: Piloting Potential App Features*<br>o Pilot testing can be carried out with users and experts.<br>o Using the interactive mock-ups, conduct (three iterations of) focus groups to pilot test the proposed mHealth app features and gather feedback for further design improvements and refinements.<br>o Consult with experts of the targeted health behaviour to verify content of the mHealth app.<br>o Create pilot testing summary results table on interactive mock-ups (outlining themes; sub-themes; usability codes; user experience codes; feedback quotes from focus group participants).<br>• *Step 10: Refining App Features, Generating Content and Developing the App Prototype*<br>o Aims to integrate the theoretical, user-centred and app feature specifications of the mHealth app intervention's design and delivery.<br>o Complete the Final Intervention Mapping table – mapping stages 1, 2 and 3 (stage 1: COM-B and TDF theoretical components; sub-themes; stage 2: user preferences; intervention functions; BCTs; and stage 3: app features).<br>o Content generation: review empirical evidence and existing apps to creating content for messages, message framing (e.g. gain vs loss), notifications, quiz questions, tips, hints, motivation messages, etc.<br>o Create a content table (COM-B; TDF; BCTs; example messages, questions, notifications)<br>o Create artificial detailed scenarios to provide user journey flows through the app's features and functionalities.<br>o Develop a refined (final) app prototype. |
| 7. Artefacts, design boundary objects and | **Artefacts utilised at main stages and phases:**<br>**Stage 1: Integrate**<br>• Phase 1: Qualitative user need findings methods: observations, interviews, focus groups, questionnaires, surveys. | **Artefacts utilised at main process stages and steps:**<br>**Stage 1: Understanding the Problem and User Preferences**<br>• Step 1: Review literature and empirical study findings; stakeholder meetings. |

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| supporting methods | • Phase 2: Qualitative study findings; literature and empirical study findings.<br>• Phase 3: Evidence-based theory-driven behavioural strategies; literature and empirical study findings; CALO-RE Taxonomy; BCTT v1; process motivators.<br>• Phase 3: The IDEAS "Toolkit of Behavioural Strategies for Process Motivation" for guiding the mHealth intervention's design.<br><br>**Stage 2: Design**<br>• Phase 4: Brainstorming and creative idea generation techniques and methods; users' insights (literary and empirical); defined target behaviour; theory-driven and theory-based behavioural strategies; divergent thinking techniques.<br>• Phase 5: Prototyping techniques and methods (e.g. parallel, sequential); input from iteration cycles between user feedback (phase 6) and further ideation (phase 4); prototyping materials, resources and software.<br>• Phase 6: User testing methods and techniques (e.g. usability testing, surveys, in-depth interviews, informal conversations, think aloud technique); target user participant representatives.<br>• Phase 7: Final prototype design solution; guidelines for managing multi-disciplinary MVP decision-making process; resources for building MVP(s).<br><br>**Stage 3: Assess**<br>• Phase 8: Pilot testing techniques and methods (e.g. usability and user satisfaction questionnaires, scaling tools and interviews; data usage patterns); pilot testing design and implementation procedures.<br>• Phase 9: RCT-ready MVP version; RCT best practice guidelines [e.g. randomisation and bias; CONSORT-eHEALTH (best practice reporting recommendations particularised to mHealth interventions); MARS (mHealth App Rating Scale)].<br><br>**Stage 4: Share**<br>• Phase 10: Resources to support dissemination.<br><br>**IDEAS artefact (form or template) from Stages 1 to 4 (Phases 1 to 10):**<br>• The IDEAS Checklist (32 boxes to check).<br><br>**Artefacts produced at main stages and phases:**<br>**Stage 1: Integrate**<br>• Phase 1: Qualitative user needs study results and findings; define broad health behavioural intervention goal (e.g. increase physical activity). | • Step 2: Empirical formative research findings with target population, behavioural experts, and other relevant consultants and stakeholders to inform specific target behaviour selection.<br>• Step 3: Statement on selected target behaviour informs specification; target behaviour specification table template.<br>• Step 4.1: COM-B; TDF; qualitative empirical study methods (mainly focus groups) and study results.<br>• Step 4.2: UCD; qualitative empirical study methods (mainly focus groups) and study results.<br><br>**Stage 2: Translating Research Findings into App Features**<br>• Step 5: Focus group discussion sessions; selection criteria for "accept/reject" decision process; commercial app company consultants.<br>• Step 6: Table output from step 4.1; the BCW.<br>• Step 7: Table output from step 6; health psychologists (participation for review and verification); CALO-RE Taxonomy; BCTT v1.<br>• Step 8: Table outputs from step 4.2 and 7; commercial app company consultants and designers; software engineer consultants; gamification techniques; UML modelling.<br><br>**Stage 3: Pre-Testing and Refinement**<br>• Step 9: Graphical interactive mock-ups (output from step 8); focus group participants; target behaviour experts; usability heuristics; user experience principles.<br>• Step 10: COM-B Behavioural Diagnosis table (step 6 output); Theory-Intervention Function-BCT map (step 7 output); BCT-UCD App Translation table (step 8 output) together informs the Final Intervention Mapping table.<br><br>**Artefacts produced at main stages and steps:**<br>**Stage 1: Understanding the Problem and User Preferences**<br>• Step 1: Definition statement of overall health problem; socioecological systems diagram centring target audience (figure).<br>• Step 2: Focus group/expert findings; statement on selected target behaviour.<br>• Step 3: Specification statement on target behaviour and context; target behaviour specification (table) (who, when, where, how often, with whom).<br>• Step 4.1: Qualitative empirical studies results and findings; COM-B Behavioural Diagnosis (table) (COM-B; TDF; quotes); List of main COM-B and TDF topics. |

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| | • Phase 2: Define specific target behaviour (e.g. take 10 000 steps each day); target measure for mHealth intervention success/effectiveness.<br>• Phase 3: List of theory-driven and theory-based behavioural change strategies (or BCTs), delivery mediums and intrinsic process motivators; results of the team's preparation for the brainstorming phase.<br><br>**Stage 2: Design**<br>• Phase 4: Brainstorming technique and method outputs (e.g. idea generation products, board/wall displays, graphical and visual representations, models, sketches, mind mapping); multi-disciplinary team brainstorming guidelines.<br>• Phase 5: Several iterations and versions of low-fidelity and high-fidelity prototypes; wireframes; sketches; screen mock-ups; MVP versions; diagrams; storyboards; interactive, clickable software interfaces.<br>• Phase 5: Recorded prototyping process documentation/filing.<br>• Phase 6: Tracked and documented prototyping versions and iteration cycles, recorded user feedback results on various prototypes; final high-fidelity prototype; refined mHealth intervention app design prototype solution.<br>• Phase 7: Minimum Viable Product (MVP); documented MVP decisions.<br><br>**Stage 3: Assess**<br>• Phase 8: Documented pilot testing results; documented design and implementation procedures for RCT; refined MVP ready for RCT evaluation.<br>• Phase 9: RCT study results and analysed findings; refined final mHealth app intervention product based on RCT evaluation results and findings.<br><br>**Stage 4: Share**<br>• Phase 10: Publication and conference outputs; consumer app; partnerships.<br><br>**IDEAS artefact (form or template) from Stages 1 to 4 (Phases 1 to 10):**<br>• The completed IDEAS Checklist (32 boxes checked). | • Step 4.2: Qualitative empirical studies results and findings; App Feature Preference table (themes; sub-themes; quotes); List of main App Feature topics; Commercial smartphone ownership and mobile OS statistics.<br><br>**Stage 2: Translating Research Findings into App Features**<br>• Step 5: "Accept/Reject" Decision table (main theme; user preference; accept/reject decision; reasons for decision).<br>• Step 6: Theory and Intervention Function Component map (table) (COM-B; TDF; sub-themes; intervention functions; examples).<br>• Step 7: List of selected BCTs; Theory-Intervention Function-BCT map (table) (COM-B; TDF; intervention functions; BCTs).<br>• Step 8: User journey flow charts; intervention flow charts; BCT and gamification technique list; BCT-UCD App Translation table (BCTs; gamification techniques; app features); interactive graphical mock-ups of the mHealth app.<br><br>**Stage 3: Pre-Testing and Refinement**<br>• Step 9: Pilot testing summary results table (theme; sub-theme; usability codes; user experience codes; quotes); refined interactive mock-up versions;<br>• Step 10: Graphical conceptual UID screens of mHealth app; the Final Intervention Mapping table; content table; artificial detailed scenarios; refined (final) app prototype. |
| 8. Knowledge boundary contribution | • Differences in knowledge contributions by various fields are touched on throughout the paper, although the transferring, translating and transforming of knowledge across boundaries is often assumed to be a simple, easy task.<br>• Some possible disciplinary conflicting goals (objectives) are identified and discussed, such as the balancing of industry and behavioural scientist tenets when making MVP decisions. Suggestions are made to balance and reconcile different perspectives and decisions on the influences of behavioural theory, user needs and desires, and technical, financial and practical feasibility. | • Calls for greater collaboration between health behaviour change experts and the commercial app industry to address gaps in the lack of evidence-based strategies in mHealth app interventions, the lack of theoretical content, and challenges regarding app user engagement.<br>• Differences in disciplinary knowledge and terminological use (interpretive flexibility) are managed through the use of standardised languages, including COM-B model, TDF, CALO-RE Taxonomy and BCTT v1.<br>• Standardised method example is the BCW. |

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| | • Often throughout the paper methods/techniques, objects and artefacts are referred to as tools/mediums for facilitating and supporting multi-disciplinary team communication, collaboration, negotiation and knowledge sharing.<br>• Strengths and challenges are touched on regarding the balancing and opposing processes of divergent and convergent thinking, and that "high-performing teams" may be able to use this design process advantageously.<br>• The approach emphasises an engagement of heterogeneous multi-disciplinary perspectives (as a cross-sector team) which can inform the generation of more highly divergent creative ideas and innovative prototypes, shown to lead to more efficacious final mHealth intervention app designs.<br>• The paper acknowledges practical and pragmatic challenges pertaining to multi-disciplinary team work, such as dealing with conflicts and negotiations, or potential counterproductive interactions that can hinder idea generation sessions and intervention solution design improvement. However, it does not provide guidance as to how these challenges can be overcome. | • Some of the artefacts and objects discussed in the paper can be used to manage knowledge processes across knowledge boundaries, and even support heterogeneous team members on a pragmatic level.<br>• The approach is valuable in its advocation for consistent multi-disciplinary team involvement, although challenges pertaining to knowledge transfer, translation and transformation are not discussed or addressed; thereby assuming an ease through which knowledge boundaries can be crossed. |
| Limitations and lessons learned | • Less-experienced novice designers and developers may find some suggested methods and phases challenging to implement in practice.<br>• The approach acknowledges the significant importance of design in developing an effective mHealth intervention app, yet fails to incorporate principles of persuasive technology and persuasive systems design.<br>• Paper acknowledges weaknesses in perspectives often held by industry: failure to incorporate theory-based strategies (BCTs); common assumption to include and evaluate multiple behavioural strategies simultaneously; fixation with time-consuming, systematic RCTs for testing intervention effectiveness.<br>• While pilot testing and evaluation phases form part of the approach, no suggestions are made to use randomised evaluation methods of isolated intervention components (such as MOST; SMART). | • Depending on the efficacy of the multi-disciplinary team and collaborations with industry, it may take a long time before an app prototype is developed, resulting in an app design which may be outdated by the time it reaches the consumer app market.<br>• The systematic and heavily collaborative approach can be resource intensive, particularly given the diversity of expert and user participant involvement at multiple, various stages and steps of the approach. Furthermore, implementing additional refinements and app features improvements post step 10 will require further resources, financing and developer involvement.<br>• The translating of theoretical frameworks into health behavioural intervention components (functions and techniques) into mHealth app features requires skills including ongoing explicit and transparent expert communication and collaboration, creativity, and judicious decision-making processes.<br>• While the BCW and COM-B model are valuable, they are highly abstract and generalised to all health behavioural change contexts, and therefore do not consider important factors relevant to the mHealth app ecosystem.<br>• Although UCD constitutes an integral part of the approach, models of multidimensional engagement (such as the Engagement Scale) are not employed.<br>• The approach does not incorporate the BIT or BIT-Tech model which would have been valuable for instantiating techniques into app features.<br>• Health scientists would strongly critique the approach for not conducting clinical RCT evaluations to measure the app's potential effectiveness. |

## *TABLE B CONT.: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM AN INFORMATION SYSTEMS AND TECHNOLOGY PERSPECTIVE*

| Information Systems and Technology Perspective | | | |
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| **Template Criterion** | **Approach #10** | **Approach #11** | **Approach #12** |
| 1. Multi/inter disciplinary approach number and title | **Approach #10:** Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps | **Approach #11:** mHealth Intervention Design Process for Behaviour Change | **Approach #12:** Agile Development and Evaluation Approach for mHealth Apps |
| 2. Title, author and year of literature publication | Dyadic Lenses for the Motivational Design of mHealth: Bridging the Gap Between Health Theory and App Design (Geuens, et al., 2019) | mHealth Intervention Design: Creating mHealth Interventions for Behaviour Change (Smith, et al., 2016) | Agile Research to Complement Agile Development: A Proposal for an mHealth Research Lifecycle (Wilson, et al., 2018) |
| 3. Aim and summary of multi/inter disciplinary approach | The dyadic lenses aim to provide app designers and health researchers with actionable advice for translating and operationalising psychological and health theories into mHealth behaviour change intervention app design features. It bridges the two disciplinary gaps by providing cross-links between theory and implementation, and gives descriptions, guiding questions, practical examples, graphical explanations, graphical screenshot examples from real-world mHealth apps, and references for further understanding. The dyad integrates themes and frameworks from fields of persuasive technology and systems design, mobile app design, health psychology, and health behaviour change intervention development. The dyadic lenses for motivational design are particularised to the dual intra-inter(primary)personal socioecological levels of health promotion, and have been applied to the physical activity mHealth app context. | The process provides systematic and comprehensive guidance for designing mHealth behaviour change interventions over four stages. It is built on an integration of Whittaker, et al.'s (2012) process, a model of user-centred design, and three theoretical frameworks of health behaviour change. It outlines themes, subthemes and artefacts applicable to the physical activity app context. | The approach offers an agile, iterative and rapid lifecycle for designing, developing and evaluating mHealth apps. It consists of a project identification phase followed by four phases of clinical development, and includes gating questions for each stage/phase. The approach integrates themes and models from information systems, software design engineering, user-centred design, user experience design, clinical trial testing and commercial app and marketing research. It suggests using iterative A/B testing prior to clinical trial evaluation. The paper applies the approach to the pharmaceutical mHealth app context, but it is generic enough to provide insights and lessons learned for the physical activity health behaviour change app context. |
| 4. Actors and community of practice members | • The dyad generally focuses on "health app designers"; implying the integration of knowledge expertise from fields of health psychology; motivational psychology; health behaviour change; | • The paper states its contribution as a multi-disciplinary integrative approach, yet fails to explicitly identify actors (people) involved at any of the mHealth behaviour change app intervention design, development and evaluation stages. | • The approach emphasises a multi-disciplinary collaboration where all relevant stakeholders are continuously involved and engaged at all phases, and adhere to a common foundation of guidelines and recommendations. |

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| | smartphone app design and development; mHealth intervention design and development. | | • No formal list of stakeholders is provided, although actors mentioned include: project team members; academics and research centres; funding partners; app designers and developers; user experience designers; industry-academic partnerships; test engineers; government; legal structures; regulatory agencies; app platform companies (e.g. Android and Apple); target user representative participants; commercial app market users (consumers); scientists; healthcare providers. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach (intra-interpersonal aspects); mHealth and Digital Technology Perspective; Systems Thinking Approach; User Interface Design (not UCD); Human-Computer Interaction; Lifestyle Modification and Wellbeing Management; Software Engineering; Persuasive Technology; Persuasive Systems Design; Gamification.<br>**Individual and interpersonal theories:** SCT; SLT; PCT; TRA; TPB; SDT; GST; SCT; SRT; SE; SFT; ELM; HBM; TTM; IMB; SFT; SS.<br>**Theoretical basis:** reviews theories, models and core concepts on health behaviour change, psychology, communications, motivation, persuasive technology and persuasive systems design; Just-In-Time-Adaptive Interventions (JITAIs) (latent).<br>**Models and tools:** Functional Triad (Persuasion); FBM; PSDM; CALO-RE Taxonomy; BCTT v1; BCW.<br>**Existing approaches:** None. | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach (intra-interpersonal aspects); mHealth and Digital Technology Perspective; User-Centred Design; Lifestyle Modification and Wellbeing Management; Commercial (Smartphone) App Industry; Participatory Approach.<br>**Individual and interpersonal theories:** Theories of Automatic Behaviour and Habits; SRT; TPB; TRA.<br>**Theoretical basis:** based on an existing mHealth design process, and incorporates several further multi-disciplinary research contributions.<br>**Models and tools:** BCW; COM-B; CALO-RE Taxonomy; BCTT v1; APEASE Criteria; Health-ITUEM.<br>**Existing approaches:** The Development and Evaluation Process for mHealth Interventions (Approach #6); | **Perspectives:** Health Science; Socioecological Approach (broader environmental aspects); Clinical Medicine; mHealth and Digital Technology Perspective; Systems Thinking Approach; Agile Systems Development; Product Development; User Experience Design; Human-Centred Design; User-Centred Design; User Interface Design; Pharmaceutical Sciences; Software Engineering and Software Design; Commercial (Smartphone) App Industry; Consumer Market; Participatory Approach.<br>**Individual and interpersonal theories:** None.<br>**Theoretical basis:** reviews existing approaches such as IDEAS (Approach #8), best practice recommendations such as the CONSORT-eHEALTH Checklist, and agile adaptive technology and software engineering design methodologies.<br>**Models and tools:** Agile Software Development Model; Design Thinking Model.<br>**Existing approaches:** The Agile Systems Development Lifecycle; Software Engineering Development Process; IDEAS (Approach #8). |
| 6. Components of the multi/ inter-disciplinary approach | **The Dyadic Lenses main components:**<br>• The Dyadic Lenses: Core Elements and Concepts<br>• Left of the Dyad: Lens of Features<br>• Right of the Dyad: Lens of Theories<br>• The Dyadic Set of Lenses: Cross-Links<br>**Nature of approach components:**<br>• Iterative; pragmatic; theory-based; evidence-based<br><br>**The Dyadic Lenses: Core Elements and Concepts** | **mHealth Intervention Design Process main stages:**<br>• Stage 1: Conceptualisation<br>• Stage 2: Formative Research and Pre-Testing Activities<br>• Stage 3: Pilot Trials<br>• Stage 4: Evaluation Trials<br>**Nature of approach stages:**<br>• Iterative; systematic; linear; cumulative; theory-based; evidence-based | **mHealth Agile Development Lifecycle main phases:**<br>**Project Stage**<br>• Phase 0: Project Identification<br>**Clinical Development Stage**<br>• Phase 1: User-Experience Design, Development and Alpha Testing<br>• Phase 2: Beta Testing<br>• Phase 3: Clinical Trial Evaluation |

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| | • Motivational design: the process arranging resources and procedures to bring about changes in motivation.<br>• Motivational features (= PDPs + BCTs): combined set of persuasive design principles and behaviour change techniques intentionally embedded in a smartphone app. Features that specifically aim to form, alter, reinforce or deter health attitudes and behaviours, or aim to increase intervention compliance or adherence.<br>• The lenses templates are similar to design patterns used for user interface and software design.<br><br>**Left of the Dyad: Lens of Features**<br>• Twenty-six (26) motivational design features<br>• *Aim:* provide guidance for operationalisation (instantiation) of psychological theory at the app feature implementation level.<br>• *Offers*: designers and developers a short description explaining how a motivational feature works.<br>• *Cross-Links*: interactive bridge links to corresponding (grounding) psychological theories.<br>• *Presents*: one to four inspiring questions for designers and developers to ask themselves to help them identify the motivational feature, and how it can be incorporated in an app.<br>• *Provides*: two to three concrete real-world graphical/illustrative examples of motivational feature implementations in current existing mHealth apps; showing app screen interfaces and references the consumer app names (and OS).<br>• *6 categories and 26 features in the lens:*<br>o Ability (reduction; tunnelling; instruction; rehearsal; reminders).<br>o Information (general information; macro tailoring; micro tailoring; simulation).<br>o Awareness and personal insights (logging; tracking; self-monitoring; goal setting; suggestion).<br>o Incentivisation (rewards; praise; recognition). | **Stage 1: Conceptualisation**<br>• *Aim:* based on the theory- and evidence-based Behaviour Change Wheel (BCW) and COM-B, create and conceptualise the mHealth intervention's design.<br>• Conceptualisation covers three sub-stages:<br>o (1) Understanding the health behaviour – which include four steps:<br>▪ (1.1) Defining the problem in behavioural terms – create a behavioural problem statement (table) that specifies the relevant locations (context) and participants (target audience) (BCW).<br>▪ (1.2) Selecting target behaviours – create a list of potential behaviours to facilitate changing the problem behaviour (BCW).<br>▪ (1.3) Specifying the target behaviours – create a specification of who would perform the target behaviours, what they need to do differently to achieve the change, where and when they need to do it (in what context), and if necessary, how often and with whom (BCW).<br>▪ (1.4) Identifying what needs to change to achieve the target behaviour(s) – create a Behavioural Diagnosis specifying what needs to change (COM-B).<br>o (2) Identifying intervention options – identify and select intervention functions (of nine specified in the BCW)<br>o (3) Identifying content and implementation options – covering two steps:<br>▪ (3.1) Identifying behaviour change techniques (BCTs) – aligned with valid target behaviour determinants (CALO-RE Taxonomy, BCTT v1).<br>▪ (3.2) Identifying the mode of delivery – using the APEASE Criteria, select an | • Phase 4: Post-Market Surveillance<br>**Nature of approach phases:**<br>• Iterative; flexible; dynamic; cyclical; rapid cyclical; continuous feedback loops/cycles; cumulative; non-linear; evidence-based<br><br>**Project Stage (Phase 0)**<br>**Phase 0: Project Identification**<br>• *Main tasks:* problem identified; user research; solution conception; funding acquisition; team member establishment; partner engagement; market analysis.<br>• Identify challenge (health problem) and identify target market.<br>• Stipulate product vision; initiate project.<br>• Identify multi-disciplinary team members; establish initial project and team requirements.<br>• Secure project funding and resources.<br>• Three sample gating questions, concerning the health problem, resources, business model and target market.<br><br>**Clinical Development Stage (Phases 1 to 4)**<br>**Phase 1: User-Experience Design, Development and Alpha Testing**<br>• *Main tasks:* UXD/UID; iterative user testing; functional prototype development; Alpha testing; quality assurance; accessibility; conformance; privacy and security assessment.<br>• *User Experience Design (UXD):* rapidly and iteratively develop and evaluate the proposed product designs (conceived as sketches, storyboards and wireframes) using cyclical user and user interface design testing (feedback loops).<br>• *Aim of UXD testing:* ensure the product design incorporates an understanding of the target user's needs, values, context, abilities, strengths and limitations – iterate until criteria are met.<br>• During UXD iterative refinement cycle: start building an initial functional Alpha app prototype. |

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| | o Social interactions (social identification; social comparison; competition; cooperation; social encounters).<br>o Trustworthiness and liking (personalisation; verifiability; expertise; surface credibility).<br><br>**Right of the Dyad: Lens of Theories**<br>• Twelve (12) psychological theories<br>• *Aim:* provide guidance for understanding the psychological theoretical foundations grounding/ underlying motivational features.<br>• *Offers*: designers and developers a description of the psychological/health theory, and the main founding scientific author of the theory.<br>• *Cross-Links*: interactive bridge links to corresponding motivational features.<br>• *Presents*: a graphical representation of the core concepts of the theory, and also lists and explains the theory's psychological drivers in detail to further illustrate how the theory works.<br>• *Provides*: references to main credible sources containing more information about the theory.<br>• *12 theories and core concepts in the lens:*<br>o Theory of Reasoned Action (TRA) (attitude; subjective norm; behavioural intention).<br>o Theory of Planned Behaviour (TPB) (attitude; subjective norm; perceived behavioural control; behavioural intention).<br>o Self Determination Theory (SDT) (competence; autonomy; relatedness).<br>o Information Motivation Behavioural Skills Model (IMB) (information; motivation; behavioural skills).<br>o Health Belief Model (HBM) (personal characteristics; perceived susceptibility; perceived severity; perceived threat; perceived benefits; perceived barriers; cues to action; likelihood of behaviour).<br>o Operant Conditioning (reinforcement; punishment). | appropriate platform to for delivering the BCTs (e.g. smartphone app).<br><br>**Stage 2: Formative Research and Pre-Testing Activities**<br>• *Aim:* translate and refine the mHealth app intervention's conceptualisation into a prototype that supports user behaviours, use contexts and user preferences.<br>• Use quantitative and qualitative methods to pre-test the app's concept and inform how it'll be translated into a working prototype. Conduct formative research with target user representative participants and use the Health-ITUEM framework and criteria as a guide (measuring objective and subjective factors).<br>• Aim of user participant studies is elicit feedback for understanding users' acceptance, engagement, preferences, information needs and user flows.<br><br>**Stage 3: Pilot Trials**<br>• *Aim:* refine the mHealth app intervention prototype into a finalised app in preparation for a larger RCT evaluation trial/study.<br>• Conduct a short-term trial period with target user representative participants (e.g. over one month).<br>• Assess: mHealth app usage and functionality, and users' experiences, perspectives, criticisms, suggestions, feedback.<br>• Users complete written surveys and complete a Health-ITUEM survey at the end of the pilot study.<br>• Develop a finalised working app prototype ready for long-term evaluation testing.<br><br>**Stage 4: Evaluation Trials**<br>• *Aim:* tests the mHealth app intervention in a controlled research study (RCT) and a real-world context. | • *Alpha testing:* functional prototype enters alpha testing, involving project team members and test engineers.<br>• *Aim of Alpha testing:* evaluate and determine if functional app prototype performs its intended use; eliminate bugs and other critical issues.<br>• *Alpha testers' feedback:* refines product design; new features; informs further design and A testing iteration cycles.<br>• *Conduct assessments of functional app prototype:* technical security and vulnerability; privacy; risk; barriers; accessibility standards (WCAG 2.0).<br>• Output: functional Alpha app prototype ready for Beta testing – functional prototype complete.<br>• Seven sample gating questions, covering product use, accessibility and user preferences.<br><br>**Phase 2: Beta Testing**<br>• *Main tasks:* end user testing; cohort studies; case series designs; limited production release.<br>• Input: functional Alpha app prototype.<br>• *Beta testing:* functional prototype enters beta testing, involving project team members and target user representative participants.<br>• *Conduct more formal user testing studies:* determine whether functional prototype meets users' needs in ways leading to sustainable adoption; evaluate acceptability, accessibility and willingness of product use against patient (user) demographics to identify barriers, equity issues.<br>• *Study types:* cohort; case series; end-user testing; surveys; interviews; focus groups; analytics data.<br>• *Beta testers' feedback:* refines product design; feasibility, context and validity with users; informs further design and Beta testing iteration cycles.<br>• *Between cycles loop:* usability, acceptability and feasibility feedback loops back to Phase 1. |

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| | o Goal Setting Theory (GST) (specificity; difficulty; acceptance; goals; commitment; performance; feedback; goal achievement).<br>o Social Facilitation Theory (SFT) (social presence of others; arousal; social facilitation; social inhibition).<br>o Social Cognitive Theory (SCT) (self-efficacy; outcome expectations; modelling; socio-structural factors; goals; identification).<br>o Elaboration Likelihood Model (ELM) (central route; peripheral route; cognitive response; belief change; attitude change; behaviour change).<br>o Transtheoretical Model (TTM) (precontemplation; contemplation; preparation; action; maintenance; termination; progress; relapse; self-efficacy; decisional balance).<br>o Perceptual Control Theory (goal-action-perception; action-condition-target; feedback).<br><br>**The Dyadic Set of Lenses: Cross-Links**<br>• *Cross-Links*: the lens of features link to the different theoretical concepts that may ground of contextualise the feature; and the lens of theories link to the different features that lend support to the operationalisation (instantiation) of the theoretical concept. | • *Purpose:* determine the objective-quantitative effectiveness (Clinical) and subjective-qualitative feedback measures (using Health-ITUEM). | • Output: functional Beta app prototype ready for clinical trial evaluation (limited production app release) – successful Beta app candidate.<br>• Five sample gating questions, relating to users' use preferences, feasibility and acceptability, context implementation and validity.<br><br>**Phase 3: Clinical Trial Evaluation**<br>• *Main tasks:* randomised controlled trials (RCTs); A/B testing; fractional factorial testing; adaptive design testing methods.<br>• Input: functional Beta app prototype.<br>• *Low vs high risk:* determine if app is low risk (clinical trial testing is not necessary but can be beneficial) or high risk (clinical trial testing is necessary to meet medical treatment standards).<br>• *Conduct clinical trial studies:* generate and determine whether product addresses the initially defined challenge (Phase 0).<br>• *Aim of clinical trials:* evaluate efficacy, usefulness, effectiveness, credibility.<br>• *Study types:* RCTs; A/B testing; fractional factorial experimental design testing; adapted trial design methods; continuous experimentation methods.<br>• *Formal evaluation study results:* refines and improves app product design and development.<br>• *Between cycles loop:* user feedback and formal evaluation study results loop back to Phase 1.<br>• Output: commercial release of app product to public (users/consumers) – successful release app candidate.<br>• One sample gating question, regarding evidence for the product's problem-solving effectiveness.<br><br>**Phase 4: Post-Market Surveillance**<br>• *Main tasks:* ongoing user support and feedback; technical maintenance; privacy and security monitoring.<br>• Input: commercial release of app product. |

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| | | | • *Perform post-market surveillance:* monitor safety; generate and respond to ongoing user feedback and defect reports; app product use analytics (Google Analytics, app download and usage statistics, within app usage tracking).<br>• Respond to constantly changing landscape, technology advancements, market changes by c*onducting continuous evaluations of app's:* relevance, usefulness, usage; safety of use; technological and clinical effectiveness.<br>• Continuous technological updates.<br>• Monitor and evaluate ongoing maintenance costs; cost/benefit ratio.<br>• *Between cycles loop:* user feedback and defect reports loop back to Phase 1.<br>• Output: commercial app remains updated and available on consumer app market.<br>• Three sample gating questions, concerning relevance, safety, accuracy, value, maintenance and further improvement. |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts of the Dyadic Lenses:**<br>• The dyadic lenses are a valuable boundary object (in and of itself) for bridging the gap between psychological health behavioural theory and smartphone app design.<br>• Inherent artefacts utilised within the dyad include the CALO-RE Taxonomy; BCTT v1; PSDM and gamification taxonomies.<br>• Other design artefacts incorporated include screen mock-ups, design sketches, wireframes, prototypes and app design instantiation software. | **Artefacts utilised at main stages:**<br>• Stage 1: BCW (template) for sub-stage 1's steps 1.1 to 1.3; COM-B for a behavioural diagnosis in step 1.4.<br>• Stage 1: BCW (9 intervention functions) for sub-stage 2; CALO-RE Taxonomy and BCTT v1 for sub-stage 3's 3.1; APEASE Criteria for 3.2.<br>• Stage 2: Quantitative and qualitative methods (user journey walkthroughs, user feature walkthroughs, focus groups, usability testing); the Health-ITUEM framework and criteria.<br>• Stage 3: Prototyping software; app prototype development materials and resources; participant representative users; Health-ITUEM, surveys.<br>• Stage 4: RCT method; focus groups; commercial app users.<br><br>**Artefacts produced at main stages:** | **Artefacts utilised at main phases:**<br>• Phase 0: User and target market research; partnership engagement meetings; business model (if it exists); literature and empirical evidence findings; project documentation.<br>• Phase 1: UXD and UID testing methods and guidelines; target user report; materials and resources for Alpha development and testing; test engineer consultants; assessment guidelines and templates for: quality assurance, accessibility standards (WCAG 2.0), conformance, risks, barriers, privacy and security.<br>• Phase 2: Alpha app prototype (main input); formal user testing methods, guidelines and ethics; user demographics; target user representative participants.<br>• Phase 3: Beta app prototype (main input); formal clinical or adaptive trial design methods, guidelines |

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| | | • Stage 1, sub-stage 1:<br>  o Step 1.1: Statement of health behavioural problem (table) [type of behaviour; location (context); participants (target audience)].<br>  o Step 1.2: List of potential facilitating behaviours (list).<br>  o Step 1.3: Specification of selected target behaviours (list) (who; what; where; when; how often; with whom).<br>  o Step 1.4: Behavioural Diagnosis.<br>• Stage 1, sub-stage 2: Intervention functions (list or matrix table)<br>• Stage 1, sub-stage 3:<br>  o Step 3.1: List of BCTs (list).<br>  o Step 3.2: Mode of delivery specification.<br>• Stage 2: mHealth app intervention conceptualisation; quantitative and qualitative results and study findings; refined prototype ideas.<br>• Stage 3: Final working app prototype; pilot study results and findings.<br>• Stage 4: mHealth app intervention's objective and subjective measures and user feedback. | and ethics; problem definition specification; risk assessment template; public user participants.<br>• Phase 4: Commercial app product release (main input); post-market surveillance guidelines and report templates; app data and usage analytics software; evaluation methods for use, utility, safety, quality, accuracy, value, efficacy, effectiveness; technical maintenance guidelines; funding and resource reports.<br><br>**Artefacts produced at main phases:**<br>• Phase 0: Problem definition specification; user research and consumer/commercial market analytic reports; business model; target market specification; target user report; project documentation; funding and resource reports; multi-disciplinary team documentation and guidelines; gating questions and answers report.<br>• Phase 1: UXD and UID design artefacts (e.g. sketches, storyboards, wireframes); test engineer feedback results; UXD and UID testing results; Alpha app prototype (version reporting and documentation); complete functional Alpha app prototype; gating questions and answers report.<br>• Phase 2: User feedback and Beta testing results; Beta app prototype (version reporting and documentation); complete functional Beta app prototype ready for release; gating questions and answers report.<br>• Phase 3: Commercial app prototype as public release candidate; Clinical and adaptive trial testing results; app evaluation evidence findings report; gating questions and answers report.<br>• Phase 4: Updated final commercial app available on consumer app market; defect reports; continuous user feedback and market reports; market surveillance reports; maintenance reports; gating questions and answers report. |

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| 8. Knowledge boundary contribution | • The paper recognises differences in interpretive flexibility of terminology between the two main disciplines (health behavioural intervention sciences and app features design), making mention of terms such as 'attrition', 'compliance', 'adherence'.<br>• A valuable strength of the dyadic lenses is that they offer cross-links between theoretical concepts (psychological drivers) and app features (operationalised and instantiated design features), with the intention of supporting the translation of theoretical knowledge into motivational app design features. Offers actionable advice to app designers and allows them to implement features while retaining links to health behaviour theory and theoretical concepts. | • The approach explicitly aims to facilitate the integration of knowledge from health behavioural change intervention design and BCTs with knowledge from user-centred design feedback processes. The paper however fails to discuss challenges or provide guidance regarding how the different knowledge crosses multi-disciplinary boundaries and can be integrated in the face of alternate paradigmatic views (health science vs information systems).<br>• Differences in terminological use such as usability and acceptance are not acknowledged or addressed by the authors. | • The approach recognises the value of multi-disciplinary knowledge contributions and combines a variety of methods from different applicable fields of expertise (e.g. software engineering and design; agile app development; technology; commercial market; health and clinical development and testing; legislative and government standards).<br>• The approach emphasises a "co-design" perspective where all relevant stakeholders are continuously and actively engaged throughout the whole agile lifecycle process – during the app's ongoing iterative design, development and evaluation cycles.<br>• The paper suggests the multi-disciplinary team be supported by a "common foundation of guidelines and recommendations". Although this is not discussed further, it points to the facilitating and managing of the team and knowledge contributions throughout the process.<br>• The paper explicitly advocates for the agile development's emphasis on "face-to-face collaboration and interactions between developers and customers as the best mechanisms to create effective solutions for the end user". However, it does not address how these collaborations, interactions, cooperations and negotiations can be facilitated and managed.<br>• The paper acknowledges a conflict of interests between software and app developers and researchers and health intervention designers. Developers generally perceive investments in research as wasted resources, wasted funding and as something that slows down the creative and innovative app design and development process. This represents an inherent conflict of interest in the relative importance placed on theory vs practice.<br>• The approach acknowledges the value offered in continuously incorporating feedback, knowledge |

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| | | | and information offered by app users and the commercial app market. |
| 9. Limitations and lessons learned | • The main limitation of the approach is that it is more of a framework or model than a series of stages, phases or steps. It does, however, provide a valuable contribution to the general mHealth app "design and development" aspect of the whole process. It would be useful within existing approach process stages such as the mHealth Intervention Development and Evaluation Process "Conceptualisation" step 1 (Approach #6); and the BIT Model's components 2, 3 and 4 (Approach #7); the IDEAS "Design" main stage 2 (Approach #8); and the mHealth App Intervention Development "Translating" stage 2 (Approach #9).<br>• The interdependency between the lenses and theory carries an inherent reliance on the validity of psychological theories. In the event that theoretical models and constructs are contested and redefined, the lenses' validity is affected, and adaptations would need to be made accordingly.<br>• The dyad includes only the traditional health behavioural change related psychological theories and fails to incorporate more recently proposed integrated and adapted theories such as HAPA, Social Networking (SN) theories, Social Media Health Interaction Theory, Adult Learning theories, Ely's Change Model, and dynamic behavioural models (e.g. Dynamic Model of Relapse).<br>• The dyad makes no mention of context- and health behaviour- specific theories such as the Integrated Behavioural Change Model for Physical Activity. Moreover, health behavioural theories adapted to the technological context are not incorporated, such as Just-In-Time Adaptive Intervention (JITAI) models; Health-ITUEM; and the Unified Theory of Acceptance and Use of Technology (UTAUT) model. | • The approach acknowledges the importance of multi-disciplinary knowledge integration, yet fails to identify specific actors involved in the collaborative mHealth behaviour change app intervention design process.<br>• The application of the COM-B model in stage 1, sub-stage 1's step 1.4 does not incorporate use of the TDF, which Susan Michie (the BCW and COM-B models' primary author) specifies as valuable for elaborating on behaviour change theories.<br>• The approach only selects and considers the "mode of delivery" – a smartphone app – at the stage 1 sub-stage 3, step 3.2. Prior to this stage, the conceptualisation process fails to acknowledge how the selected platform influences what can and cannot be integrated when designing and developing a health behaviour change intervention on a digital technology smartphone app platform.<br>• The pre-testing, pilot testing and evaluation trial stages rely heavily on using the Health-ITUEM framework and criteria as an evaluation measure. The Health-ITUEM is valuable, yet rigid reliance on this tool comes at the expense of employing other valuable evaluation techniques and tools such as MOST, MARS, TIPs, incremental and fractional factorial experiment testing, CONSORT-eHEALTH.<br>• The approach emphasises the integration of a user-centred design perspective, although it does not consider models of multidimensional user engagement (such as the Engagement Scale).<br>• No mention is made of knowledge boundaries and the processes or challenges concerning the integrating of knowledge from multiple disciplines.<br>• The approach does not provide practical guidance for translating or operationalising intervention | • The approach is highly resource and funding intensive.<br>• The rapid, iterative and quick design, development and evaluation of the app requires a highly skilled and experienced team.<br>• Novice designers and developers may struggle to implement the approach effectively and efficaciously, and without experienced guidance may result in a failed project with considerable lost resources, time and funding.<br>• The approach fails to integrate theory completely.<br>• The approach fails to incorporate work on intervention strategies, components and health behaviour change techniques; despite evidence demonstrating its relationship to mHealth app effectiveness.<br>• The approach emphasises the importance of good app design, yet fails to discuss or incorporate guidance on the operationalisation and translation of design concepts and ideas into app design features.<br>• Existing app market solutions are not incorporated in the app design process, which could provide valuable insights into which features are generally received well by consumers. Not reviewing existing designs may lead the team to reinvent the wheel unnecessarily, wasting time and resources.<br>• The approach provides a valuable lesson in its heavy weighting on the commercial app industry and consumer app market perspectives. This integrates a product development perspective that views mHealth apps as products, rather than just interventions, which complements the commercial app industry and acknowledges that ultimately, the app product will need to be made available for public consumers on app market stores. |

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| | • A challenge lies in possible oversimplification and reductionism if designers avoid contextualisation and naively interpret and apply theories and features without proper understanding. This issue corresponds with possible limited applications of the dyadic lenses by focusing on easy forms of implementation or remaining narrow-scoped to the specific graphical examples provided.<br>• The paper fails to discuss or provide guidance to designers for selecting and prioritising theories and features. Designers may not be aware that some theoretical perspectives are rooted in diverse fields and may at times be opposing or contradictory (or even complementary), which in turn affects the actionable implementation and effective potential of the app's features. This issue goes in tandem with possible naïve interpretations and applications of the lenses by designers.<br>• Lack of mHealth app intervention design and development experience may hinder the effective utilisation and application of the dyadic lenses. | components and BCTs into mobile app design features.<br>• A useful lesson offered by the approach is its consideration for the commercial mobile app industry, although little is discussed about this important stakeholder involvement in the multi-disciplinary mHealth app intervention design process. | • The approach offers considerable value in its integration of Alpha and Beta app prototype versions, which emphasises iterative, agile and rapid design and evaluation cycles – an approach suitable to the rapidly changing digital mobile technology and smartphone app landscapes.<br>• An insightful lesson is offered in the incorporating of A/B testing from agile software engineering.<br>• Adaptive clinical trial testing methods are discussed as formal evaluation approaches, shifting from a heavy sole reliance on traditional gold standard, large RCT evaluations.<br>• A valuable lesson is offered in incorporating gating processes in mHealth app design, development and evaluation phases; the app intervention is required to meet gating standards before being allowed to progress to the next phase. A limitation however is that the sample gating questions are not exhaustive, but intend to encourage team discussion and thought at all of the phases.<br>• The approach offers new insights and lessons by including safety, privacy, risk, efficacy, accuracy, sustainability, quality, effectiveness, commercialisability, and thorough testing.<br>• The approach makes early mention of aligning the workflows of publishing platforms (Apple's App Store; Google Play) into the app's design and development cycles, although it makes no mention of this alignment in any of the phases. |

## *TABLE C: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM A PARTNERSHIP PERSPECTIVE*

| Partnership Perspective | | |
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| **Template Criterion** | **Approach #13** | **Approach #14** |
| 1. Multi/inter disciplinary approach number and title | **Approach #13:**<br>The Person-Based Approach for Developing Digital Health Behaviour Change Interventions | **Approach #14:**<br>Participatory Design Approach for Stakeholder Engagement in Quality Health Behaviour Change Intervention Development |
| 2. Title, author and year of literature publication | The Person-Based Approach to Intervention Development: Application to Digital Health Related Behaviour Change Interventions (Yardley, et al., 2015a) | Participatory Design for Behaviour Change: An Integrative Approach to Healthcare Quality Improvement (Carvalho, Jun and Mitchell, 2017) |
| 3. Aim and summary of multi/inter disciplinary approach | The approach aims to guide the development of digital health behaviour change interventions by focusing on understanding and accommodating the psychosocial contexts and user experience perspectives of people who will use them. It outlines two key parts for achieving this: conducting in-depth qualitative research, and producing guiding principles. This approach provides themes primarily from a health psychology and health behavioural sciences perspective, rather than a technological perspective, but can be integrated with the user-centred design process and used complementarily alongside other theory- and evidence-based approaches. The approach has been employed and applied in the mHealth physical activity behaviour change app context. | The approach emphasises a participatory process for the collaborative co-development of health behaviour change interventions. It outlines three main components, and identifies theoretical- and evidence-based artefacts (methods and tools) that foster stakeholder engagement within each stage. The paper applies the approach to a medical emergency department and urinary tract infection context, but provides themes, insights and lessons learned applicable to the multi-disciplinary collaborative and participatory design of health behaviour change interventions. |
| 4. Actors and community of practice members | • References made to actors generally include "intervention developers" and "intervention designers", as well as computer scientists; behaviour change experts; target users; and researchers (e.g. behavioural researchers). Further details on what knowledge requirements are needed to constitute an intervention developer or designer are not specified by the authors.<br>• Collaborations with programmers and flexible in-house software companies (open source software) are recommended. | • The approach generally recognises actors as "stakeholders" and as intervention designers, developers and practitioners.<br>• Given the context of application, stakeholders include: emergency department medical staff, doctors, nurses, microbiologists, healthcare researchers, managers, pharmacists, project leader(s), target user representatives. |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; Person-Centred Design; Lifestyle Modification and Wellbeing Management; User Experience Design; Qualitative Research Approach.<br>**Individual and interpersonal theories:** Brief mention of TPB; SET; SDT.<br>**Theoretical basis:** Intends to complement and enrich existing theory-based and evidence-based approaches. | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach (organisational aspects); Participatory Approach; Participatory Design; Collaborative Co-Design, Co-Development and Co-Implementation; User-Centred Design; Primary Healthcare Management and Service Delivery.<br>**Individual and interpersonal theories:** None. |

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| | **Models and tools:** BCW; Ritterband Model; CALO-RE Taxonomy; BCTT v1.<br>**Existing approaches:** Intervention Mapping (Approach #1); The CeHRes Roadmap (Approach #2); MRC Guidance (Approach #3); The Behavioural Intervention Technology (BIT) Model (Approach #7). | **Theoretical basis:** Four-phase participatory design process; four-stage BCW framework process; existing participatory design and behaviour change methods and tools.<br>**Models and tools:** BCW; COM-B; TDF; CALO-RE Taxonomy (latent); BCTT v1 (latent); Taxonomy of BC Methods; APEASE Criteria.<br>**Existing approaches:** Intervention Mapping (Approach #1); MRC Guidance (Approach #3); Person-Based Approach (Approach #13). |
| 6. Components of the multi/ inter-disciplinary approach | **Person-Based Approach main process components:**<br>• Component 1: Intervention Planning<br>• Component 2: Intervention Optimisation<br>• Component 3: Intervention Implementation<br>**Nature of approach components:**<br>• Iterative; cyclical; non-linear; systematic; cumulative; participatory; collaborative; qualitative inductive focus; theory and evidence (informs intervention planning); practical (latent).<br><br>**Component 1: Intervention Planning**<br>• *Purpose:* Intervention planning includes two phases: (1) conduct qualitative research; and (2) create guiding principles.<br>**1.1 Conduct Qualitative Research**<br>• *Aim:* Utilise exploratory and in-depth qualitative research methods (interviews, focus groups) to elicit attitudes, beliefs, perceptions, experiences, views, feelings, needs, understandings, contexts and situations relevant to target population's user characteristics (sex, gender, culture, health literacy, socioeconomic status, (dis)abilities, previous experiences). Identify intervention components (BCTs, feature designs) that are most salient, engaging, persuasive, acceptable and feasible to target users.<br>• Prior to conducting qualitative research, complete:<br>o A literature scoping and review based on existing quantitative and (relevant) qualitative primary research, systematic reviews and meta-analyses.<br>o Complete a Logic Model of the Problem (diagram) and a Logic Model of Change (diagram).<br>• Emphasise open-ended exploratory questions over close-ended questions.<br>• Example: qualitative studies with elderly persons for an exercise app revealed an alternate (positive rather than negative) orientation towards fall prevention. Qualitative findings countered prior theoretical findings on TPB.<br>**1.2 Create Guiding Principles**<br>• *Aim:* Formulate guiding principles that highlight and coherently focus the distinct and particular qualities of the intervention; providing a succinct and accessible summary of the crucial ways in which an intervention intends to | **Participatory Approach main stages:**<br>• Stage 1: Co-Definition – Understand the Behaviour<br>• Stage 2: Co-Development – Identify Intervention Options<br>• Stage 3: Co-Implementation – Identify Content and Implementation Options<br>**Nature of approach stages:**<br>• Systematic; participatory; collaborative; linear; cumulative; theory-based; evidence-based (evidence conundrum); practical.<br><br>**Stage 1: Co-Definition – Understand the Behaviour**<br>• *Aim of Co-Definition from BCW perspective:*<br>o Determine what behaviour needs to be changed by identifying: (1) what the behaviour is; (2) who performs it; (3) whom it is performed with; (4) where it is performed; (5) how frequently it occurs.<br>• *Aim of Co-Definition from PD perspective:*<br>o A comprehensive description of the problem space that incorporates the multiple perspectives, priorities and concerns of all heterogeneous stakeholders/parties involved.<br>• *Shared Aim*: Develop a shared understanding of the problem space.<br>• *Methods and tools from BCW perspective:*<br>o COM-B Model; BCW worksheets 1 to 4.<br>• *Methods and tools from PD perspective:*<br>o User interviews; focus groups; user forum; card sorting; user and care journeys; story-telling; 2D mapping; thematic (network) mapping.<br>• *Collaborative methods and tools:*<br>o Workshops; meetings with interested stakeholders and third parties; card sorting, prioritising and ordering; journey maps; group discussions; reflective discussions.<br>o Workshop #1: Shared Understanding; Workshop #2: Behavioural Challenges; Workshop #3: Evaluation Strategies.<br>• *Outputs*:<br>o Statement of Shared Understanding – common understanding of problem space.<br>o Common (shared) Knowledge Base (syntactic and semantic) |

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| | support changes in behaviour by improving engagement with the intervention's content and components.<br>• *Two elements of guiding principles:*<br>o (1) *Specification of the core design objectives* for the intervention – objectives that specify what the intervention must do in order to address the needs of the target user(s) (identified in qualitative research), and to enhance engagement with the intervention.<br>o Core design objective examples: to provide a positive, useful and rewarding experience for users; to help users maintain physical activity independently; to help people maintain exercise in the long term; to reassure people with chronic health conditions that exercise is healthy and safe for them.<br>o (2) *Key intervention features* that will support achievement of the design objectives – specifying how design objectives may be achieved in practice. Key features can specify BCTs and/or broader aspects of intervention delivery that suggest how specific BCTs will be implemented to ensure they are optimally persuasive and engaging (e.g. tone, language, mode of delivery, intended frequency of use, structure).<br>o Key intervention feature examples: build users' autonomous motivation, self-regulation skills and confidence to become their own physical activity coach; focus on creating sustainable lifestyle physical activity habits rather than relying on supervised facility-based activities; model examples of other people with similar chronic health conditions to encourage and reassure.<br>• Three common important guiding principles: promoting autonomy, promoting competence, and promoting a positive experience and relatedness.<br>• Characteristics of formulated guiding principles:<br>o Need not be exhaustive.<br>o Not intended to replace extensive documentation of how theoretical model elements of the intervention map to BCTs.<br>o Simply provide intervention designers and developers with a succinct summary for easy referral and recall.<br>• Intervention planning phase: provide a complete and generalisable map of all the generic behaviour change elements of an intervention, with the guiding principles grounded in a deep understanding of the target user's context and psychosocial orientation.<br><br>**Component 2: Intervention Optimisation**<br>• First develop an intervention prototype in order to run iterative intervention optimisation studies, refinements and modifications.<br>• *Aim:* qualitative studies are conducted to generate user feedback of the prototype(s), and gain insights into users' experiences, views, opinions and | o Group (team) cohesion statement and collaboration guiding documents.<br>o Concise visual representation (map/diagram) of multiple perspectives and complex variables constituting the problem space.<br>o Shared List of Behavioural Challenges (what, who, with whom, where, how frequently). Open to discussion – may be revised, prioritised, analysed and organised by collaborating expert stakeholders.<br><br>**Stage 2: Co-Development – Identify Intervention Options**<br>• *Aim of Co-Development from BCW perspective:*<br>o Identify the appropriate intervention functions and policy categories that relate to the specific determinants of behaviour which can predict positive changes and change outcomes.<br>• *Aim of Co- Development from PD perspective:*<br>o Investigate alternative ways of responding to the problem space, and new ways of doing things and interacting with the social and physical environments/surroundings by considering various appropriate technologies, processes, services and products.<br>• *Shared Aim*: Develop a shared understanding and vision of the solution space.<br>• *Methods and tools from BCW perspective:*<br>o COM-B Model; BCW intervention functions matrix; BCW policy categories matrix; BCW worksheets 5 and 6.<br>• *Methods and tools from PD perspective:*<br>o Co-design workshops; brainstorming; 2D and 3D prototyping; insight cards; ideas cards; scenarios; personas.<br>• *Collaborative methods and tools:*<br>o Intervention planning and logic modelling; group discussions; intervention ideas generation and refinement; ideation session with experts; interviews with participants (target users) to refine intervention ideas; prioritisation exercises.<br>o Workshop #4: Ideation and Prioritisation Group Discussions; Workshop #5: Intervention Design<br>• *Outputs*:<br>o Statement of Shared Vision – common understanding of solution space.<br>o Priority Exercises – shows differences and similarities in top solution priorities of different stakeholders involved.<br>o Priority Strategy Action Plan – deals with different solution priorities in a way that embraces complementary roles of different stakeholders and embraces the strengths of each contribution; complementary efforts are coordinated in alignment with the established prioritises of the solution.<br>o Preliminary Prototype versions. |

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| | preferences with regard to the acceptability, persuasiveness, usefulness, utility, feasibility and adherence of the intervention and its component elements (BCTs).<br>• *Aim:* user feedback informs further iterative refinements and modifications of the intervention's design (i.e. intervention optimisation) and refinements and modifications to the guiding principles.<br>• Qualitative methods at earlier prototype testing stages include observational think-aloud techniques; later prototype testing stages include piloted longitudinal studies.<br>• Findings from iterative studies are used to refine and modify the intervention's design and the design of its components and BCTs.<br>• Distinguish qualitative user feedback methods from co-design methods.<br>• Systematically document all sources of evidence and user feedback, and how findings fed into further optimisations of the intervention – record, categorise and prioritise all changes to the intervention and components/elements.<br>• Prototypes are iteratively designed, developed and optimised based on qualitative feedback. Ensure alignment (refinements and guiding principles).<br><br>**Component 3: Intervention Implementation**<br>• *Aim:* Conduct qualitative process evaluation studies to understand target users' experiences of a fully deployed intervention, and to identify potential ways to further modify the intervention (and its adherence and effectiveness) for real-world contexts and implementation.<br>• *Triangulation:* qualitative process evaluations can be triangulated with quantitative data on health outcomes, behavioural (change) determinants, and intervention usage data, to provide a clearer picture of where the intervention will work best and how it may need to be adjusted.<br>• Further refine the intervention's design and other intervention support materials (e.g. training programmes and manuals), and the guiding principles based on qualitative (and mixed method) evaluation user feedback and study findings.<br>• Develop and refine the intervention implementation plan. | **Stage 3: Co-Implementation – Identify Content and Implementation Options**<br>• *Aim of Co-Implementation from BCW perspective:*<br>o Utilise the APEASE Criteria to explore and guide decisions with regard to which BCTs and modes of delivery (means and technologies) are implementable.<br>• *Aim of Co- Implementation from PD perspective:*<br>o Identify ways in which solutions can be collaboratively implemented, tested and adjusted in accordance with the shared vision of stakeholders/parties involved.<br>• *Shared Aim*: Develop a shared understanding of the implementation and evaluation spaces.<br>• *Methods and tools from BCW perspective:*<br>o BCTT v1; CALO-RE Taxonomy; BCW worksheets 7 and 8.<br>• *Methods and tools from PD perspective:*<br>o Heuristic evaluation; usability testing and evaluations; role playing; user experience testing; piloting and trial testing.<br>• *Collaborative methods and tools:*<br>o Support materials (e.g. training and handover materials).<br>o Workshop #6: Implementation.<br>• *Outputs:*<br>o Statement of Shared Implementation Strategy and Action Plan.<br>o Shared support materials (e.g. training and handover materials).<br>o Final Prototype. |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main components:**<br>• Component 1: Literature scoping and review; existing quantitative and qualitative primary research; systematic reviews; meta-analyses. Employ relevant qualitative research methods (interviews, focus groups).<br>• Component 1: Logic Model of the Problem (diagram) and a Logic Model of Change (diagram). Utilise the formulated guiding principles. | **Artefacts utilised at main stages:**<br>• Stage 1: BCW worksheets 1 to 4; COM-B Model; methods and techniques for workshops, group discussions, focus groups, expert discussions, and user interviews; card sorting/prioritising materials and techniques.<br>• Stage 2: Outputs from Stage 1; BCW worksheets 5 and 6; BCW intervention functions matrix; BCW policy categories matrix; Intervention Mapping |

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| | • Component 2: Develop a prototype – to use for optimisation testing, refinements and modifications. Employ qualitative methods (observational think-aloud techniques, piloted longitudinal studies)<br>• Component 3: Use the refined and modified prototype. Employ qualitative process evaluation methods; and use mixed method approaches. Use the guiding principles.<br><br>**Artefacts produced at main components:**<br>• Component 1: Primary qualitative research findings; specification of target user requirements and needs; psychosocial characteristics and preferences of target population (users).<br>• Component 1: Guiding principles, including (1) description of key intervention design objectives; and (2) description of key features of the intervention in order to achieve objectives.<br>• Component 2: Prototype of intervention.<br>• Component 2: Iteratively refined and modified versions of the intervention – several prototypes. Documentation on users' feedback, and how feedback informed further modifications, refinements and iterations of the prototypes.<br>• Component 2: Refined (updated) guiding principles (report/document).<br>• Component 3: Triangulated (mixed method) process evaluation study results (adherence, effectiveness, persuasiveness, feasibility, acceptance, use) of the intervention implemented in real-world contexts.<br>• Component 3: Refined (updated) guiding principles based on triangulated findings. | Modelling techniques and diagramming (Approach #1); ideation methods and techniques.<br>• Stage 3: Outputs from Stage 2; BCW worksheets 7 and 8; Preliminary Prototype versions; pilot testing and evaluation methods and techniques; APEASE Criteria; BCTT v1; CALO-RE Taxonomy.<br><br>**Artefacts produced at main stages:**<br>• Stage 1: Shared Understanding Statement (of the problem space); Common Knowledge Base; Group (team) cohesion statement and guiding documentation; Visual representation map (diagram); Shared List of (prioritised) Behavioural Challenges.<br>• Stage 2: Shared Vision Statement (of the solution space); Results of Priority Exercises; Priority Strategy Action Plan (for collaborative and cooperative solution space); Preliminary Prototype versions.<br>• Stage 3: Shared Implementation Strategy and Action Plan Statements; Shared Support Materials and Training Materials; Final Prototype. |
| 8. Knowledge boundary contribution | • A succinct and accessible summary of the intervention plan and guiding principles can enable and enhance communication across different disciplines and knowledge arenas, to support multidisciplinary collaboration and facilitation of stakeholder involvements, meetings, events and consultations.<br>• The authors suggest the approach be utilised in conjunction with human-centred design and technology orientated design frameworks.<br>• Clarified understanding of how terminology is defined in the specific approach versus other disciplinary perspectives, including terms: user; human; person; usability; usability testing; user experience; acceptability, effectiveness; patient; engagement; satisfaction; trust; motivating; enjoyability; persuasiveness; informative; convincing; outcomes. | • The approach acknowledges the value of combining, creating and using (BCW and PD) boundary objects, methods and tools to support and facilitate the development of shared understandings (of the problem space), shared visions (of the solution space) and shared implementation strategies for collaborative and cooperative priorities of action and evaluation strategies. This includes the creation of a common knowledge base (operating at syntactic and semantic levels), and a collaborative coordinated plan that prioritises the different, albeit complementary, stakeholder goals and contributions to the shared space. These boundary objects support consistent engagement between multiple heterogeneous stakeholders, users and implementers (developers) in order to coordinate collaborative intervention development efforts.<br>• The approach acknowledges that a multi- and transdisciplinary approach to health behaviour change intervention design and development requires the integration and facilitation of different philosophical perspectives, each offering different methods and tools. |

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| | • The highlighted distinctions in how terms are understood speaks to the interpretive flexibility of language within the overlapping multi-disciplinary health behaviour change intervention design and development space.<br>• Given clarifications of alternative interpretations, the health behavioural intervention design and development team can be supported in terms of syntactic (transfer) and semantic (translation) knowledge boundaries (and processes). | • Participatory design includes the collaborative efforts for creating: co-definitions of problems, co-development of alternative, and co-implementation of solutions. This engages technical and social objectives for design, development, implementation and evaluation. Collective reflections on the development process is also recommended.<br>• Collaborative active team engagement is driven by three values: (1) having a say, (2) mutual learning, and (3) co-realisation.<br>• Co-design tools and techniques can be grouped into: (1) talking, telling and explaining; (2) making tangible things; and (3) acting, enacting and playing.<br>• Collaborative participatory efforts can be fostered through: (1) describing and visualising the multiple perspectives and contributing factors of the problem and solution space; (2) support the collaborative solution space using experimental process modelling and prototyping in 2D and 3D forms, in conceptual and concrete ways; and (3) collective and collaborative engagements foster the establishment of shared visions, articulating technical and social viewpoints and contributions. |
| 9. Limitations and lessons learned | • Most notable limitation of the approach is its biasing towards the health psychology and health behavioural science perspectives, at the overt expense of the technological and digital design perspectives, as well as theory- and evidence-based development approaches. This limitation is acknowledged by the authors, to which they suggest the Person-Based Approach be used complementary to user-centred design, user experience design, and theory- and evidence-based approaches. They however do not provide guidance as to how the Person-Based Approach can be used with other approaches, not do they explicitly identify which other multidisciplinary approaches.<br>• A valuable lesson the paper touches on is a limitation of co-design methods: that users are generally unable to accurately anticipate or predict the needs, experiences, views and preferences of other users. Users are helpful in providing feedback on what they like and dislike, but not skilled in generating effective BCTs and suggesting good design solutions.<br>• Valuable lesson in insight to focus on gathering users' feedback on which intervention elements and components are likely to be the most important in a specific context with a particular target population, and guidance on how to implement them in a way that is persuasive, acceptable, useful and feasible for users with those particular target population characteristics.<br>• Limitation in that intervention developers require thorough in-depth health, behavioural, cognitive, emotional, attitudinal and social psychological understanding in order to create Guiding Principles. The authors for instance provide an example guiding principle which states an intervention design objective "to help people to main their [physical] activity independently" translating into the key feature "digital intervention to build autonomous motivation, self-regulation skills (e.g. graded goal setting and self-monitoring) and confidence to become their own physical activity coach". This | • The approach is valuable in its recognition for the importance of creating shared understandings, shared visions, and shared implementation and action plans. This supports and facilitates knowledge across heterogeneous boundaries, and aims to not ignore or reject different perspectives and alternative knowledge contributions.<br>• The approach provides a valuable alternative perspective on participatory design for health behaviour change interventions that aims to overcome the "evidence conundrum" (i.e. an overemphasis of quantitative evidence and research methods in behaviour change research and practice) and encourages the "need for a more transdisciplinary approach to behaviour change" (from different philosophical perspectives, holding different methods and tools).<br>• Although the approach advocates for collaborative, cooperative and coordinated efforts, it fails to provide detailed guidance on how these multiple efforts and contributions can best (or optimally) be leveraged and harvested.<br>• A notable limitation of the approach is that it only considers the "mode of delivery" – that is, technology as a platform for delivery – at the third stage.<br>• The approach does not focus on technology and digital devices as platforms for delivering health behaviour change interventions.<br>• Together with this limitation, the approach does not acknowledge the difficulties faced in translating BCTs and intervention components into design features, and how the selected mode of delivery |

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| | competency to translate such a design objective would require an intervention developer to already hold comprehensive knowledge of psychological theory.<br>• It is not a standalone approach. The authors suggest not using it to replace current approaches, but rather to complement and rich existing theory- and evidence-based approaches (such as MRC Guidance, Approach #3). They recommend: "the Person-Based Approach could be usefully incorporated within a multi-disciplinary holistic human-centred design framework [or approach] … to help implement the participatory and persuasive design aspects".<br>• Valuable lesson offered in intervention design and development process that emphasises the gaining of insights into how different people in different situations and contexts perceive, experience, adopt and implement/execute elements of behavioural change interventions, and why some elements are particularly salient or necessary for them, and why others are problematic or aversive – ultimately informed a more persuasive, attractive, meaningful and feasible digital health behavioural intervention solution.<br>• In comparison to other approaches that concern persuasion, usability, user experience, usage and usability with technological design features, this the Person-Based Approach offers an alternate valuable lesson in examining the same constructs but against behavioural change techniques, and not technological features. | (platform) affects how an intervention can be designed, developed, implemented and evaluated.<br>• The approach biases the BCW as a theoretical grounding for the Behaviour Change perspective.<br>• The proposed approach is limited in its application to the primary healthcare, emergency department and urinary tract infection contexts specifically. Although, it nevertheless provides valuable insights into how the three-stage participatory collaborative method aligns with and complements the three-stage behaviour change wheel model process. This alignment helps identify where shared and overlapping boundaries are between disciplines, where shared spaces can be fostered for collaborative work, and where knowledge can be crossed and joined. |

## *TABLE C CONT.: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM A PARTNERSHIP PERSPECTIVE*

| Partnership Perspective | | |
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| **Template Criterion** | **Approach #15** | **Approach #16** |
| 1. Multi/inter disciplinary approach number and title | **Approach #15:**<br>Co-Design Approach for Developing Tailored mHealth Behaviour Change Intervention Apps | **Approach #16:**<br>Multi-Disciplinary Thematic Seminars as a Collaborative Design Method for Health Information Systems Development |
| 2. Title, author and year of literature publication | Using Co-Design to Develop a Culturally Tailored, Behaviour Change mHealth Intervention for Indigenous and Other Priority Communities: A Case Study in New Zealand (Verbiest, et al., 2018) | From User Needs to System Specifications: Multi-Disciplinary Thematic Seminars as a Collaborative Design Method for Development of Health Information Systems (Scandurra, Hägglund and Koch, 2008a) |
| 3. Aim and summary of multi/inter disciplinary approach | The approach integrates six steps of participatory co-design with four steps for mHealth behaviour change app design, and incorporates an evidence-based theoretical health behavioural change framework. It emphasises themes on the participatory involvement of target users for developing a tailored, culturally-appropriate healthy lifestyle management app. The paper describes links | The MdTS method makes use of thematic seminars as a collaborative tool for eliciting user needs from different perspectives, and aims to identify points of intersection to establish a common ground for cooperative multi-disciplinary work. It details themes and subthemes on shared understanding, cooperative work processes and practices, joint activity workflows, interpretive flexibility, shared |

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| | between health behavioural change determinants, intervention components, and mHealth app design features. The approach is applicable to different mHealth behaviour change app contexts. | artefacts and communication tools. It also discusses themes on facilitators of multi-disciplinary teams, and guidelines for supporting cooperative work. The MdTS method is based on methods of participatory design, user-centred systems design, human-centred design, and computer supported cooperative work. It is applied to the healthcare information systems context, but provides valuable insights for multi-disciplinary teams designing health intervention apps. |
| 4. Actors and community of practice members | • The approach emphasises a community-academic partnership – a partnership between community members (the target population) and an academic mHealth intervention research team.<br>• Community members involve health practitioners and target end users from two indigenous cultural communities in New Zealand, the Māori and Pasifika tribes. Cultural expert consultants were also approached and involved.<br>• The academic team included graphic designers, smartphone application designers and developers; consultants; public health researchers and practitioners; public health intervention designers and developers; physical activity and nutrition knowledge experts and specialists. | • The multi-disciplinary team primarily involves Health Informatics-Usability (HI-U) specialists; intra-care professionals; inter-care professionals.<br>• Other stakeholders include usability and HCI experts; clinical professionals; end users; buyers; owners; operational services; hardware and software designers and developers; organisation managers.<br>• Actors relevant to the application context and HIS developed (a virtual health record VHR system) included: general practitioners (GPs); district nurses; home help service personnel; technical group (technical infrastructure, architecture design, software development, technical implementation and support); scientific group (project evaluation from different perspectives). |
| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; Participatory Design; Collaborative Co-Design; User-Centred Design; User Experience Design (latent); Lifestyle Modification and Wellbeing Management.<br>**Individual and interpersonal theories:** None.<br>**Theoretical basis: T**he Kaupapa Māori Co-Design Process was combined with Bratteteig's Participatory Co-Design Process Model as the basis for guiding the development of the mHealth lifestyle behaviour change app.<br>**Models and tools:** TDF; CALO-RE Taxonomy; BCTT v1; the Te Whare Tapa Whā (Model for Māori Health); the Te Pae Mahutonga (Model for Māori Health Promotion); and the Fonofale (Model for Pasifika Health).<br>**Existing approaches:** No existing approaches are utilised or adapted. | **Perspectives:** Socioecological Approach; Computer Supported Cooperative Work (CSCW); Health Information Systems; Clinical and Medical Perspective; Healthcare Service Delivery; Participatory Approach; Participatory Design; Socio-Technical Perspective; User-Centred Design; Innovative Thinking Perspective; Systems Thinking Approach; Soft Systems Methodology; Hardware and Software Architecture; Software Engineering and Software Design.<br>**Individual and interpersonal theories:** None.<br>**Theoretical basis:** The MdTS method (grounded in CSCW); activity theory; Checkland's SSM; future workshops theory; vision seminars.<br>**Models and tools:** No specific models or tools are referenced.<br>**Existing approaches:** No existing approaches are utilised or adapted. |
| 6. Components of the multi-inter-disciplinary approach | **mHealth Co-Design Process main steps:**<br>• Step 1: Opportunity Identification and Partnership Building<br>• Step 2: Elucidation of Needs and Desires and Knowledge Generation<br>• Step 3: Description of mHealth Intervention Requirements<br>• Step 4: Envisaging the mHealth Intervention Tool<br>• Step 5: Iterative mHealth Intervention Development and Prototype Testing<br>o Step 5.1: Identify Key Content Modules<br>o Step 5.2: Identify Relevant Determinants of Behaviour Change<br>o Step 5.3: Select Appropriate BCTs<br>o Step 5.4: Incorporate the BCTs in the mHealth Intervention | **MdTS method seminar themes:**<br>**Pre-Seminar Work**<br>**Holistic Perspective**<br>• Seminar Theme 1: Project Start-Up – Introduction<br>• Seminar Theme 2: Current Work Situation<br>• Seminar Theme 3: Organisation in Practice<br>• Seminar Theme 4: Information and Community Handling<br>• Seminar Theme 5: Technical Workshop<br>• Seminar Theme 6: Future Work Perspective |

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| | • Step 6: mHealth Intervention Prototype Evaluation<br>**Nature of approach steps:**<br>• Iterative; cyclical; systematic; cumulative; non-linear (linear aspects 5.1-5.4); theory-based; evidence-based; participatory; collaborative.<br><br>**Step 1: Opportunity Identification and Partnership Building**<br>• *Aims:* (1) Identify an opportunity for partnership and intervention, and (2) establish and build a partnership between an academic research team and community partners.<br>• *Activities:* assemble partners from both academic and community sides; conduct face-to-face partnership meetings; formally define the project culture and partnership agreement; establish team culture and relationship values/principles; define project values; frame research parameters; establish a conflict and tension resolution agreement.<br>• Use group and collective discussions to establish partnership agreements.<br>• *Collaborative partnership tools:* use online platforms to support and facilitate communication between partnership members for the duration of the mHealth Intervention project.<br><br>**Step 2: Elucidation of Needs and Desires and Knowledge Generation**<br>• *Aim:* Establish an understanding of what aspects of health and wellbeing are important to the community.<br>• Conduct focus groups (facilitated by coordinators) and utilise methods (such as metaphors and storytelling) to elicit expressions and discussions of users' thoughts, needs, desires and ideas.<br>• Questions relate to: hopes and dreams; needs and desires; what health and wellbeing means; lifestyle behaviour interests; barriers and difficulties associated with lifestyle behaviours; preferences and thoughts regarding mHealth digital technologies; generating ideas about what is important.<br>• Use various means of collecting data from focus groups and group exercises: photographs, audio recordings, visual recordings, reflection worksheets, white boards, paper.<br>• Statements of community members' needs and desires.<br><br>**Step 3: Description of mHealth Intervention Requirements**<br>• *Aim:* Identify the main requirements for the mHealth Intervention.<br>• Conduct focus groups and utilise idea generation (ideation) methods and techniques to elicit the main requirements for the mHealth intervention. | **Detailed Perspective**<br>• Seminar Theme 7: Current Work Scenarios – Intra-Care Professional<br>• Seminar Theme 8: Current Work Scenarios – Inter-Care Professional<br>• Seminar Theme 9: Detailed Analysis of Information Needs<br>• Seminar Theme 10: Future Work Scenarios – Intra-Care Professional<br>• Seminar Theme 11: Future Work Scenarios – Inter-Care Professional<br>• Seminar Theme 12: Visualisation of Future Work Scenarios<br>**Nature of method seminars:**<br>• Iterative; cyclical; reflective; non-systematic (need not be consecutive); non-linear; cumulative; participatory; collaborative; theory-based; evidence-based; practical (latent).<br><br>**Pre-Seminar Work**<br>• HI-U specialists conduct field studies, observations and interviews to understand current work situations and to capture users' tacit knowledge.<br>• *Two types of multi-disciplinary seminars:*<br>o (1) Intra-care professional group seminars – focus is orientated towards one healthcare profession's work.<br>o (2) Inter-care professional group seminars – focus is orientated towards the cooperative aspects of work.<br><br>**Holistic Perspective**<br>• *Aim:* create common ground by creating a platform where participants can gain an overview of each other's work processes, and can obtain a mutual understanding of the entire cooperative work space.<br>**Seminar Theme 1: Project Start-Up – Introduction**<br>• *Actors:* Multi-disciplinary team (all stakeholders involved in the project).<br>• *Activities:* get-together activities including the project model; project rules, regulations and guidelines; project team contract and collaborative work agreement (formalised, signed); work descriptions; project aims; project ideas.<br>• *Homework:* None.<br>• *HI-U specialists:* document and disseminate project regulations, contracts and guidelines.<br>**Seminar Theme 2: Current Work Situation**<br>• *Actors:* HI-U specialists and inter-care profession group.<br>• *Activities:* conduct a "context of use" questionnaire with all users – users evaluate present work practices and environment; ethical issues are discussed.<br>• *Homework:* "Describe a day at work". |

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| | **Step 4: Envisaging the mHealth Intervention Tool**<br>• *Aim:* Explore possible ideas for an mHealth Intervention solution that represents and aligns with the community's requirements, needs and desires.<br>• The solution generally tends towards an importance placed on a collectivist and less material envisagement.<br>• Bus-Stop activity: community members in the focus group are asked to engage with different existing mHealth apps for 5 minutes each, and are asked to identify what they like and dislike, and discuss these features and functionalities in groups.<br>• Use creative materials and expressive techniques to physically elicit community members' envisioned features and functionalities (e.g. colourful moulding putty, shapes, cut-outs, fluffy pom-poms, gift bow ribbons, beads, etc).<br><br>**Step 5: Iterative mHealth Intervention Development and Prototype Testing**<br>• *Aim:* Conduct iterative partnership engagements and focus groups to design, develop and pilot test the mHealth Intervention over time (a 3-month period in this paper's case application). This constitutes a process of cyclical and continual refinement based on ongoing input and feedback from community members/partners.<br>• *Aim:* Focus on identifying, determining and refining content, features and functionalities of the smartphone mHealth Intervention.<br><br>**Step 5.1: Identify Key Content Modules**<br>• *Aim:* The academic research team summarise the main themes relevant to health and wellbeing, identified from the focus groups with the community members.<br>• Example content modules: physical activity, healthy eating, weight management, social support and motivation, alcohol consumption, mental wellbeing, stress management.<br>• Ask community members to rank and prioritise content modules based on importance (scale 1 to 5).<br><br>**Step 5.2: Identify Relevant Determinants of Behaviour Change**<br>• *Aim:* The academic research team identify which behavioural change determinants and change factors would impede and enable change in relevant health behaviours.<br>• The qualitative data findings from focus groups and discussions with community members are reviewed to elicit culturally-relevant determinants. | • *HI-U specialists:* analyse results – user analysis, task analysis, environment analysis (iteration 1).<br>**Seminar Theme 3: Organisation in Practice**<br>• *Actors:* HI-U specialists and inter-care profession group. Managers invited.<br>• *Activities:* contextual inquiry; analysis of current work in groups; HI-U guides a summarisation of problems, difficulties, need for change during field work; managers are invited to explain their point of view of change management and in particular, changes within the organisation; information gathered on different roles and how people feel about their jobs/work.<br>• *Homework:* "Describe your organisation".<br>• *HI-U specialists:* analyse results – extended environment analysis of social, cultural and organisational analyses.<br>**Seminar Theme 4: Information and Community Handling**<br>• *Actors:* HI-U specialists and inter-care profession group.<br>• *Activities:* categorising of information; gather current documents; conduct detailed task analysis to understand the current system and information flows within it (why, when, where, how, by whom documents are used, and exceptions when not used); examples of carrying out single tasks in cooperative work environment.<br>• *Homework:* "Describe your desire for improved communication".<br>• *HI-U specialists:* analyse results – overall general description of information and communication flows.<br>**Seminar Theme 5: Technical Workshop**<br>• *Actors:* HI-U specialists and inter-care profession group. Professionals invited: HCI specialists; hardware and software solution and enterprise architects.<br>• *Activities:* full day workshops on selected presentations, hands-on working sessions, guided discussions covering critical evaluations and HCI lectures; discussions on new technology (pros, cons, design, functionalities, features).<br>• *Homework:* None.<br>• *HI-U specialists:* knowledge about preferred hardware and software features and functionalities; non-functional requirements specification in close cooperation with solution and enterprise architects.<br>**Seminar Theme 6: Future Work Perspective**<br>• *Actors:* HI-U specialists and inter-care profession group.<br>• *Activities:* future workshops envisioning future work practices – developing a vision, ideas and action plan among participants, identifying obstacles.<br>• *Homework:* "If you were the boss…" and "Describe a day at work in the future".<br>• *HI-U specialists:* analyse results – task analysis (iteration 2) – general task description of future work. |

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| | Relevant health behaviour theory- and evidence-based determinants (domains) are identified from the TDF, and are compared to the community member determinants to identify similarities and overlaps.<br>• Examples: knowledge; social support and engagement; empowerment.<br><br>**Step 5.3: Select Appropriate BCTs**<br>• *Aim:* Match theory- and evidence-based BCTs with the co-design focus group findings from community members, and the determinants.<br>• Use the BCTT v1 and CALO-RE Taxonomy to select BCTs deemed suitable and appropriate for facilitating health behaviour change.<br>• Examples of BCTs: competitiveness, social support, knowledge.<br>• Create a table linking examples of co-design findings with determinants and BCTs (to address each determinant).<br><br>**Step 5.4: Incorporate the BCTs in the mHealth Intervention**<br>• *Aim:* Incorporate the BCTs into features and functionalities of the mHealth Intervention.<br>• Collaborate with graphic designers and smartphone application developers to produce app designs and function flows for community members to provide feedback and opinions on.<br>• Use the feedback from community members to iteratively refine and improve the prototype designs.<br>• Add to the table by articulating how BCTs will be incorporated as features and functionalities in the mHealth intervention app.<br>• Examples: notifications for general information; GPS location tagging; physical activity progress and goal monitoring feedback; culturally-appropriate reward system.<br>• Emphasis is placed on designing graphical user interfaces and app design features that are culturally-sensitive and appropriate (e.g. Māori symbols and weapons; coconut trees; Māori mountains near lived location).<br>• Four culturally-distinct app prototype versions were developed to gather further feedback from community members regarding terminology and language usage, as well as culture-specific food items, practices, customs, traditions, and activities related to the health behaviours.<br><br>**Step 6: mHealth Intervention Prototype Evaluation**<br>• *Aim:* The selected final prototype undergoes trial evaluation testing with community members, and feedback is gathered on the final app can be further refined and improved. | **Detailed Perspective**<br>• *Aim:* analyses results from the holistic perspective by examining points of intersection and the specific details for each involved profession, as well as identify the items necessary for developing an integrated HIS.<br>• *Aim:* further conducts hands-on multi-profession workshops in which participants from a range of heterogeneous backgrounds (professions) take advantage of each other's ideas of how to improve work practices.<br>**Seminar Theme 7: Current Work Scenarios – Intra-Care Professional**<br>• *Actors:* HI-U specialists and intra-care profession group.<br>• *Activities:* scenario descriptions containing detailed work situations for and by every profession contributing to the integrated care; preliminary prototypes are used to verify the requirements.<br>• *Homework:* "What would your profession need considering today's work?".<br>• *HI-U specialists:* analyse results – detailed scenario descriptions for each profession and work situation functional specification – use case modelling and use case specification work begins.<br>**Seminar Theme 8: Current Work Scenarios – Inter-Care Professional**<br>• *Actors:* HI-U specialists and inter-care profession group.<br>• *Activities:* inter-care professional groups discuss perspectives on requirements and needs; a current work scenario-puzzle is created with cooperative work activities. Workflows of cooperative activities are tested using paper prototypes; general task descriptions (from seminar 6) form the basis for the homework.<br>• *Homework:* "What would your profession need to improve cooperation, if you consider the current integrated care work?".<br>• *HI-U specialists:* analyse results – detailed scenario descriptions for a cooperative environment – functional specifications with use case modelling and use case specifications revised and improved.<br>**Seminar Theme 9: Detailed Analysis of Information Needs**<br>• *Actors:* HI-U specialists and intra- or inter-care profession group.<br>• *Activities:* analyses of individual and cooperative information needs using current documentation, work scenarios and prototypes; detailed descriptions of information needed for integrated care.<br>• *Homework:* "Given your needs are met, how would it change your daily work?".<br>• *HI-U specialists:* conceptual database model, use case specifications verified.<br>**Seminar Theme 10: Future Work Scenarios – Intra-Care Professional**<br>• *Actors:* HI-U specialists and intra-care profession group.<br>• *Activities:* future workshop focuses on detailed work activities for each profession. Homework from seminars 8 and 9 and general task descriptions of future work (from seminar 6) form the basis of the future workshop; awareness |

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| | • The evaluation period can span from a few months to a year.<br>• Evaluation outcomes measured include: behaviour changes, health outcomes, weight changes, lifestyle differences, app effectiveness, app usability, frequency of use, intervention adherence, preferred features. | of organisation's change needs, some work processes are prioritised, future work scenarios are created.<br>• *Homework:* "Given your needs are met, how would you cooperate?" and "In what way would IT change your daily cooperative work?".<br>• *HI-U specialists:* representational analysis – preliminary prototypes for prioritised work processes.<br>**Seminar Theme 11: Future Work Scenarios – Inter-Care Professional**<br>• *Actors:* HI-U specialists and inter-care profession group.<br>• *Activities:* collaborative future workshop focuses on comparing prioritised work process and goals; work scenarios focus on activities for improved collaborative work; preliminary prototypes are used to test ideas; key processes in cooperative care are identified and detailed descriptions of activities for future collaborative work are specified.<br>• *Homework:* "Get back from colleagues on future work scenarios".<br>• *HI-U specialists:* representational analysis – preliminary prototypes based on use case specifications for future work.<br>**Seminar Theme 12: Visualisation of Future Work Scenarios**<br>• *Actors:* Multi-disciplinary team (all stakeholders involved in the project).<br>• *Activities:* future work activities are tested using preliminary prototypes in close and real work situations; role-plays; video recordings; reflection period to aid discussions on scenarios and analysing cooperative work processes; feedback is gathered regarding future work scenarios and ICT tools.<br>• *Assignment:* "Test your cooperation".<br>• *HI-U specialists:* hand-over final use case specifications for future work to system developers. |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main steps:**<br>• Step 1: Partnership agreement contracts and guideline forms; partnership methods and techniques (focus groups, group discussions); online platforms for partnership collaborations and communications.<br>• Step 2: Partnership methods and techniques (focus groups, group discussions); focus group question guidelines; focus group exercises and materials.<br>• Step 3: Outputs from step 2; partnership focus group method and technique.<br>• Step 4: Outputs from step 3; creative materials and expressive techniques; bus stop activity guidelines; focus group method and technique.<br>• Step 5: Iterative prototype design, development and testing method and guidelines; focus group method and technique; prototyping materials; TDF; | **Artefacts utilised at thematic seminars:**<br>• Pre-Seminar Work: Fields observations, master-apprenticeship and contextual design method; task analyses; user analyses; environment analyses; interviews with professionals.<br>• Seminar Theme 1 to 12: Intra- and inter-care group professionals; HI-U specialists; seminar discussion guidelines; homework sheets and questions; use case modelling worksheets; work process and work scenario worksheets.<br><br>**Artefacts produced at thematic seminars:**<br>• Pre-Seminar Work: Current work situation analysis (users, tasks, processes, environment, problems, difficulties, coordination, communication).<br>• Seminar Theme 1 to 12: Homework outputs; HI-U specialist outputs – including results analyses; task, user, context and environment analyses; current and future |

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| | community member focus group findings; BCTT v1; CALO-RE Taxonomy; graphic designers; smartphone app designers and developers.<br>• Step 6: App prototype version(s) for evaluation and trial testing.<br><br>**Artefacts produced at main steps:**<br>• Step 1: Academic-community member partnership agreement; partnership meeting protocols; partnership team culture and relationship values and principles; project culture and agreement; research parameters; partnership conflict and tension resolution agreement; focus group facilitators and coordinators.<br>• Step 2: Statements of community members' needs and desires. Knowledge generation findings (answered questions).<br>• Step 3: Statement of mHealth Intervention Requirements.<br>• Step 4: Envisagement of mHealth Intervention Tool.<br>• Step 5: Step 5.1: Key Content Modules (ranked and prioritised). Step 5.2: Identified Determinants of Behaviour Change (community and TDF comparison). Step 5.3: Selection on BCTs; Table of Determinants and BCTs (linking co-design findings, determinants and BCTs). Step 5.4: Table of BCT Integration (linking co-design findings, determinants, BCTs and mHealth app design features and functionalities). Prototype versions, community member feedback findings and prototype refinement documentation.<br>• Step 6: Final mHealth Intervention app; evaluation and trial findings; evaluation outcome measures. | work situation specifications; use case specifications; work processes and work scenarios; detailed scenario descriptions; preliminary prototypes.<br><br>**Boundary objects and artefacts:**<br>• Detailed task analysis; communication flows (maps and diagrams); detailed scenarios; prototypes; technical specifications; use case modelling diagrams and worksheets.<br>• Paper sketching: a tool used in the early stages to facilitate communication between stakeholders and minimise the risk for potential misunderstandings between heterogeneous participants (from different knowledge backgrounds). Paper sketching also provides a means of tangibly documenting ideas during and between the holistic perspective seminars.<br>• Prototypes: digital prototypes are continuously revised, tested, refined and improved.<br>• Shared terms, definitions and objectives. Common language and terminology descriptions.<br>• Visual communication tools to facilitate a common picture of work practices, provided by iterative preliminary prototypes that illustrating proposed work scenarios, possible chain reactions and consequences for other professions.<br>• Documentation developed by HI-U specialists after each thematic seminar are circulated back to all other stakeholders to ensure every party is on the same page and up-to-date with developments. |
| 8. Knowledge boundary contribution | • The approach acknowledges and incorporates partnership agreements throughout the design, development, pilot testing and evaluation stages.<br>• Collaborations, communications and partnership discussions are supported and facilitated through group interactions, facilitated by focus group coordinators.<br>• The approach does not discuss how clarifications are made between community members and academic team actors in cases of ambiguity and uncertainty (e.g. if community members do not understand aspects of BCTs and intervention components).<br>• Weight is implicitly placed on the academic team to elevate community member provided feedback into health behavioural and intervention knowledge that will be useful for prototype development. | • The approach emphasises all stakeholders (actors) be present at the project start-up, and that consensus be reached regarding the team members' common goals and strategies.<br>• All seminars are facilitated by an external role (actor) who can hold a 'birds-eye view' of the process. Competencies include: balancing different requests from all stakeholders, and keeping a focus on usability. The paper describes this boundary and knowledge facilitator as a "Health Informatics-Usability (HI-U) Specialist" – holding knowledge, expertise and skills in both health informatics and human computer usability design. They need to be "fluent in the languages of both" worlds/knowledge arenas.<br>• The paper acknowledges professionals within one discipline as likely to hold little to no knowledge on other disciplines' work processes and practices.<br>• Multi-disciplinary team work requires the establishment of common (mutual) understanding and common ground between healthcare professionals and technology developers. Common ground includes: work routines and processes, information demands and central preconditions. Common ground is imperative for supporting cooperative work processes where different professionals (from different perspectives) hold different objectives and specialist knowledge skills. |

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| | | • The collaborative development process should consider various social, organisational and cultural factors relating to the cooperative work processes.<br>• Real target users need to contribute to the development process given they hold relevant knowledge and understanding of actions and consequences. Challenges are faced in their lack of knowledge and expertise regarding systems/digital technology development and healthcare services or health behaviours.<br>• Progress reports and outputs from each seminar are continuously assembled and handed to all other stakeholders (team members) throughout the collaborative process (by HI-U specialists). |
| 9. Limitations and lessons learned | • The close partnership with community members is valuable in that it allows the academic team to elicit and ascertain requirements, ideas, BCTs, features, functionalities and designs that are preferred by the community.<br>• The approach emphasises the establishment of partnership agreements from the start of the project.<br>• The approach requires intensive time and resources to facilitate numerous focus group discussions over a long period of time. Challenges may be encountered in maintaining community members' active engagement and partaking in the participatory partnership process from beginning to end. Further challenges may be encountered in who facilitates and coordinates all focus group discussions – relating to ethics and consistency. The paper does not specify the knowledge and skills required for facilitating the discussions.<br>• A significant volume of weighting is placed on the academic team to continuously review, revise and analyse feedback, opinions and contributions from the community members.<br>• The paper does not discuss how differences in specialist knowledge and perspectives (particularly between health psychologists and health behaviourists, and mHealth app developers) can be collaboratively resolved.<br>• The approach does not consider the difficulties faced in translating BCTs into technical mHealth features, and the limitations and barriers presented by the digital platform.<br>• The main limitation of the approach is its suiting to culturally-sensitive contexts, which is valuable for small target groups, but cannot be generalised to other target populations. The findings of one project cannot be utilised in other mHealth intervention projects. | • Incorporating a CSCW perspective is valuable in that it emphasises the need to address cooperative work processes and practices, and involve all relevant stakeholders throughout the process. Proper guidelines to support and facilitate cooperative work processes and practices are imperative.<br>• A significant limitation is the focus on the first step of the systems development process – the elicitation of users' needs in cooperative multi-disciplinary work, and the transformation of users' needs into detailed requirements specifications for the development of new health information systems. The approach therefore does not incorporate cooperative work processes and practices for supporting phases of technological design, development and evaluation.<br>• Another notable limitation of the approach is its application to the healthcare service delivery context, rather than the health behaviour change intervention context. The authors however argue that the approach can provide general applicability to other multi-disciplinary cooperative work process contexts.<br>• An important limitation is the MdTS method's application to the HIS rather than digital technology (particularly the smartphone app) context.<br>• The approach is limited in that it is highly time-intensive. Running 12 series of thematic seminars (or more including the iterations) is very time-consuming and resource intensive. These seminars also rely heavily on participant buy-in and commitment throughout the project.<br>• A noteworthy limitation of the approach is its emphasis and heavy reliance on HI-U specialists from beginning to end, giving rise to an extensive workload.<br>• Challenges and difficulties arise in that consensus needs to be reached at the end of every seminar. |

## *TABLE D: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM AN INTEGRATIVE PERSPECTIVE*

| Integrative Perspective | | |
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| **Template Criterion** | **Approach #17** | **Approach #18** |
| 1. Multi/inter disciplinary approach number and title | **Approach #17:**<br>Holistic Framework for Developing Digital Health Behaviour Change Interventions: TUDER | **Approach #18:**<br>Multi-Disciplinary Approach for the Agile Development of Gamified mHealth Behaviour Change Intervention Apps |
| 2. Title, author and year of literature publication | Integrating Taxonomies into Theory-Based Digital Health Interventions for Behaviour Change: A Holistic Framework (Wang, et al., 2019) | Creating a Theoretically-Grounded, Gamified Health App: Lessons from Developing the Cigbreak Smoking Cessation Mobile Phone Game (Edwards, et al., 2018) |
| 3. Aim and summary of multi/inter disciplinary approach | The framework provides an iterative and comprehensive process and two integrated taxonomies for designing, developing and evaluating digital health behavioural change interventions. It consists of four steps, two toolboxes, a workflow and a checklist. TUDER is based on existing approaches (IDEAS, the CeHRes Roadmap, the BIT and BIT-Tech models, and the PSDM), and integrates models from different fields including health behavioural intervention sciences, health psychology and theory, persuasive technology and systems design, information systems, digital health technology and just-in-time adaptive intervention technology. It details themes and subthemes on multi-disciplinary knowledge integration, methods and artefacts. The approach's earlier version details valuable themes and insights particularised and applied to the context of mHealth physical activity behaviour change intervention apps. | The approach offers a collaborative and iterative seven step process for developing theoretically-informed and evidence-based gamified mHealth behaviour change apps. It emphasises an expert multi-disciplinary design team theme during the development process. The integrative approach incorporates an existing approach (MRC Guidelines), and combines themes and models from fields of health psychology, health behavioural change intervention sciences, information systems and systems design, engineering, computer science, gamification and game development, and user experience design. The paper's case application is to a mHealth smoking cessation app, but the approach is applicable to other mHealth behavioural change app contexts. |
| 4. Actors and community of practice members | • The main actors involved in the multi-disciplinary process are referred to as "DHI designers" and "DHI developers".<br>• Some disciplines mentioned include: public health; behavioural science; health psychology; behavioural, cognitive and social psychology; human-computer interaction (HCI); usability and user interface design; user experience design; mobile computing; smartphone application design and development; target users; and other stakeholders. | • The approach emphasises multi-disciplinary design team engagement and collaboration throughout the whole mHealth app development process.<br>• Mobile and smartphone app designers and developers; healthcare professionals.<br>• The multi-disciplinary design team comprised: several academic researchers; one senior smartphone app developer; two computer scientists; two clinical doctors; one senior health psychologist; one senior medical sociologist; several health behaviour experts and specialist advisors (from a formal smoking organisation and programme).<br>• Additional members for focus groups included public and potential consumer app users (as representative target users of the smoking population).<br>• Other potential actors include: game designers and developers. |

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| 5. Underlying theories, models and existing approaches | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; Persuasive Technology; Persuasive Systems Design; User-Centred Design (latent); Human-Centred Design (latent); Lifestyle Modification and Wellbeing Management; Human-Computer Interaction.<br>**Individual and interpersonal theories:** Individual and interpersonal level theories discussed in the paper include: SE; TTM; SCT; HBM; TPB; TRA; IMB; SDT; HAPA; SLT; SRT; SGT; Theories of Automatic Behaviour and Habits.<br>**Theoretical basis:** Several approaches, models and taxonomies are reviewed, incorporated and integrated for informing the TUDER Holistic Framework; Just-In-Time-Adaptive Interventions (JITAIs).<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; PSDM; PSD Principles.<br>**Existing approaches:** Intervention Mapping (Approach #1); The CeHRes Roadmap (Approach #2); The Behavioural Intervention Technology (BIT) Model (Approach #7); Wendel's Approach (Wendel, 2013); The IDEAS Framework and Toolkit (Approach #8). | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; Consumer Smartphone App Market; Gamification; Agile Systems Development; User-Centred Design (latent); Lifestyle Modification and Wellbeing Management; Human-Computer Interaction; Product Design and Development.<br>**Individual and interpersonal theories:** Latent incorporation of some theories.<br>**Theoretical basis:** psychological therapy models and techniques; the Logic Model Development Guide (WK Kellogg Foundation, 2006).<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; Gamification Taxonomies and Models; British Standards Institution Code of Practice for Health and Wellness Apps.<br>**Existing approaches:** MRC Guidance (Approach #3); Development and Evaluation Process for mHealth Interventions (Approach #6); The IDEAS Framework and Toolkit (Approach #8); The mHealth App Intervention Development Process (Approach #9); The Person-Based Approach (Approach #13); The User-Centred Model for Designing Consumer mHealth Apps (Schnall, et al., 2016). |
| 6. Components of the multi/ inter-disciplinary approach | **TUDER main process steps and components:**<br>**Approach Process**<br>• Step 1: Targeting<br>• Step 2: Understanding<br>• Step 3: Designing<br>• Step 4: Evaluating and Refining<br>**Approach Components**<br>• Toolbox 1: Behavioural Theories<br>• Toolbox 2: DHI Taxonomy<br>• Workflow<br>**Nature of approach steps:**<br>• Iterative; cyclical (feedback loops); systematic; linear; cumulative; theory-based; evidence-based; comprehensive.<br><br>**Step 1: Targeting (the User Group, Health Problem and Behaviour)**<br>• *Aim:* Define the intervention aims by describing the target (user) group/population, the health problem, the health behaviour outcomes, and the targeted health behaviour.<br>• Intervention designers need to clearly articulate the linkages/relationships. Example: an mHealth app intervention to promote increased walking (the targeted health behaviour) to increase physical activity (health behaviour | **Multi-Disciplinary Approach main process steps:**<br>• Step 1: Forming an Expert Multi-Disciplinary Design Team<br>• Step 2: Defining the Problem and Establishing User Preferences<br>• Step 3: Incorporating the Evidence Base<br>• Step 4: Integrating Gamification<br>• Step 5: Adding Behaviour Change Techniques (BCTs)<br>• Step 6: Developing a Logic Model and Investigating Causal Pathways<br>• Step 7: User Testing and Developing the Final App Product<br>**Nature of approach steps:**<br>• Iterative; cyclical; rapid cyclical; systematic; linear; cumulative; theory-based; evidence-based; collaborative.<br><br>**Step 1: Forming an Expert Multi-Disciplinary Design Team**<br>• *Aim:* Form a multi-disciplinary design team of experts from heterogeneous disciplines.<br>• *Disciplines include:* Smartphone app development; computer science; game design and development; clinical and general medicine; health psychology; medical sociology; health behaviour experts and specialist advisors (in the targeted health behavioural field).<br>• *Users:* Appropriate target user representatives are sought and selected to participate in the focus groups during steps 2 to 7. |

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| | outcome) of young adults (target user group/population) in order to prevent the development of NCDs such as Diabetes Type II (the health problem).<br>• Intervention aims should be informed by evidence-based empirical studies.<br>• The target behaviour (intended to change) needs to be measurable, although the health problem need not be measurable.<br>• TUDER Checklist: Category 1, Items 1 to 3.<br>• Iterations cycle between steps 1 and 2 as the targeting and understanding phases are revised and refined.<br><br>**Step 2: Understanding (the Human Behaviour and Change Process)**<br>• *Aim:* Employ and utilise behavioural (and health psychology) theories, key theoretical constructs, and other theory-based factors and/or determinants of behaviour change to develop a theoretical base for the intervention's design and strategy components.<br>• The intervention design may be based on one theory (a behavioural theoretical model such as SCT; TTM or HAPA) or incorporate a set of theoretical constructs from several behavioural (and psychological) theories (such as attitude, perceived barriers, self-efficacy, identity, motivation, intention, action planning, goals).<br>• Linkages need to be made, and evidence provided, for the theoretical constructs and their mapping to the target user group/population, health problem, targeted health behaviour, and health behaviour outcomes.<br>• The First Version of Wang, et al.'s (2017) Holistic Framework provides details on key behavioural theories (particularly pertaining to physical activity).<br>• Toolbox 1: provides individual and interpersonal behavioural theories that can be used to understand the human behaviour and change process.<br>• TUDER Checklist: Category 2, Items 4 to 6.<br>• Iterations cycle between steps 2 and 3 as the understanding and designing phases are revised and refined.<br><br>**Step 3: Designing (the Intervention Strategies, Characteristics and Workflow)**<br>• *Aim:* Based on the intervention's ideation (conceptual idea), DHI designers and developers can select a set of strategies (of 96), and describe the characteristics of these strategies (of 6) according to the DHI Taxonomy.<br>• *Context:* The Workflow offers a contextualised representation of how an intervention can vary over time in different situations/circumstances. | • *Facilitators:* A multi-disciplinary design team facilitator is selected; a focus group facilitator and a focus group assistant are selected.<br>• *Documentation:* The multi-disciplinary design team facilitator documents and logs the team's agreed-upon consensus terminology, work processes and practices, the focus group protocols, and the decisions at all 7 steps of the development process.<br><br>**Step 2: Defining the Problem and Establishing User Preferences**<br>• *Aim:* Define the health problem and identify users' preferences.<br>• *Activities:* Define the health problem and targeted health behaviour; explore factors influencing the health behaviour and determinants for changing the health behaviour; explore factors evidenced as successful for changing the targeted health behaviour; explore user preferences for mHealth app intervention components (BCTs) and app design feature engagement.<br>• *Method:* Conduct focus groups with representative target users to elicit user preferences. More than one focus group may be held.<br>• Factors can relate to the socioecological model of health promotion, covering individual, interpersonal and social, and environmental influences. That is, social and environmental factors within one's zone of control and influence (e.g. their home environment and living space).<br>• *Outputs:* Statement of health problem and targeted health behaviour; Health behaviour determinants and factors (list); Key user preferences for intervention components (table on themes, subthemes, and user example quotes from focus groups); Key user preferences for important app appearance features (table on themes, subthemes, and user example quotes from focus groups).<br><br>**Step 3: Incorporating the Evidence Base**<br>• *Aim:* Employ and utilise existing evidence-based standards, guidelines and codes of practice to identify and guide optimal designs for the mHealth app intervention.<br>• *Activities:* Identify and elicit evidence shown to be effective in changing the targeted health behaviour (e.g. 28-day habit formation and termination); use this evidence to guide critical design aspects and components of the mHealth app intervention.<br>• Example: The MRC Guidelines (Approach #3); the British Standards Institution Code of Practice for Health and Wellness Apps; the latest up-to-date evidence-based guidelines for smoking cessation (or alternatively, the WHO recommendations for physical activity).<br>• *Output:* Documentation and list of selected evidence-based standards, guidelines and codes of practice. |

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| | • *Actors:* Emphasis is placed on involving multiple disciplinary expertise, skills and knowledge contributions for designing an effective digital solution.<br>• *Actor support materials:* Formulating clear team, process, requirement and action documents are noted as important for facilitating communication and task coordination, as well as support cooperation efficiency.<br>• Toolbox 2: offers a unified DHI Taxonomy comprising 96 intervention strategies and 6 characteristics that can be used to design the intervention.<br>• Workflow [adopted from the BIT Model (Approach #7) Instantiation Component 5 – "When": Workflow]: refers to the set of rules that determine when and under what conditions each BIT element (i.e. intervention component/technique/strategy) is delivered to an individual user over time, taking into account changes in aims, elements and/or other characteristics over the course of the intervention's delivery).<br>• The paper discusses the main workflow approaches as: time-based (e.g. reminder at 17h00 to walk); task-based (e.g. walk 10 000 steps per day); and event-based (e.g. lack of physical activity for two hours). The initial option is easiest. The two latter options are more challenging as they require automatic or manual user input to function effectively. The BIT Model (Approach #7) classifies these three all as "conditions-based" and also notes "user defined", "frequency", and "tunnelling" as workflow options.<br>• TUDER Checklist: Category 3, Items 7 to 9.<br>• Iterations cycle between steps 3 and 4 as the designing and evaluating and refining phases are revised and the intervention is iteratively improved.<br><br>**Step 4: Evaluating and Refining (the Intervention Design)**<br>• *Aim:* Evaluate and refine the design of the intervention through (1) usability and user experience testing, and (2) effectiveness testing.<br>• Usability and user experience testing aims to evaluate the digital or mHealth intervention from a HCI, UID, UXD and information systems perspective – assessing users' thoughts, feelings, experiences when interacting with the digital intervention or smartphone app.<br>o Usability and UXD methods include: think-aloud technique; cognitive walkthrough; pilot usability studies with prototypes; piloted field studies (in real-world use); heuristic evaluations and assessment checklists.<br>• Effectiveness testing aims to evaluate the digital or mHealth intervention from a Health Behavioural Science perspective – assessing the health behavioural changes, health behavioural outcomes, health outcome measures, and the intervention's acceptance, uptake, impact, feasibility and adherence.<br>o Intervention effectiveness evaluation methods include: RCTs; sequential multiple assignment controlled trials. | **Step 4: Integrating Gamification**<br>• *Aim:* Review, identify and select gamification strategies and techniques to include in the mHealth app intervention's design.<br>• *Activities:* Review and elicit gamification strategies and techniques from theory- and evidence-based gamification models and taxonomies; review gamification literature, meta-analyses and findings from empirical mHealth app studies to identify effective gamification strategies and techniques applicable for the selected target health behaviour; deconstruct the gamification strategies and techniques to align them with theory and the incorporated evidence base, and flesh out how a particular game design can include the gamification strategies.<br>• *Actors:* Emphasis is given to game designers and developers in contributing knowledge, expertise, experience and skills to step 4.<br>• Examples of gamification strategies include: Goal setting; capacity to overcome challenges (linking to self-efficacy, perceived barriers and perceived abilities); feedback on game performance; reinforcement; progress comparison measuring; social connectivity and networking; fun and enjoyment; playfulness.<br>• *Output:* Gamification strategies and techniques (table listing gamification strategies/techniques, their descriptions, and locations in the mHealth app's features, e.g. diary or game).<br><br>**Step 5: Incorporating Behaviour Change Techniques (BCTs)**<br>• *Aim:* Review, identify and select BCTs shown to be effective in changing the target health behaviour.<br>• *Activities:* Use the CALO-RE Taxonomy and BCTT v1 to identify and select active ingredients to include in the mHealth app intervention; review literature, meta-analyses and findings from empirical mHealth app studies to identify effective theory- and evidence-based BCTs suited to the target health behaviour and target group/population.<br>• *Actors:* Emphasis is placed on academic researchers and clinicians collaborating closely with a (or more) health psychologist(s) whom can advise on evidence-proven effective BCTs given the targeted health behaviour. Health psychologists (and academic researchers and clinicians) can work closely in collaboration with game and mobile app designers and developers to operationalise and instantiate BCTs into mHealth app design features.<br>• *Users:* Based on user feedback elicited from earlier focus group sessions, identify BCTs articulated as important and salient for the target group/population.<br>• Examples of evidence-based BCTs include: self-monitoring; goal setting; feedback on performance; social support; demonstration of behaviour; instruction on how to perform behaviour; rewards; prompts/cues. |

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| | • TUDER Checklist: Category 4, Items 10 and 11.<br>• Iterations cycle between steps 3 and 4 as the designing and evaluating and refining phases are revised and the intervention is iteratively improved.<br><br>**Approach Components**<br>**Toolbox 1: Behavioural Theories**<br>• Toolbox 1 provides an overview of selected individual and interpersonal behavioural (and health psychology) theories and key theoretical constructs, classified into continuum models and stage models of behaviour change.<br>• Some behavioural theories and key constructs include: SE; TTM; SCT; HBM; TPB; TRA; IMB; SDT; HAPA; SLT; SRT; SGT; Theories of Automatic Behaviour and Habits.<br>• These theories are evidenced-based and have proven to be effective in changing health and lifestyle related behaviours such as physical activity.<br><br>**Toolbox 2: DHI Taxonomy**<br>• Toolbox 2 provides a colour-coded canvas diagram of the DHI Taxonomy, including Strategies I (93 BCTs from the BCTT v1) and Strategies II (3 Principles from the PSDM) colour-coded in blue; and Characteristics I (2 Principles from the PSDM) and Characteristics II (4 Components of the BIT Model) colour-coded in green.<br>• The intervention designers and developers are able to select any strategies and characteristics deemed suitable given the target user group/population, the health problem, the targeted health behaviour, the health outcomes, and particularly evidence-based findings from reviewed literature studies.<br><br>**Workflow:**<br>• The workflow refers to the set of rules that determine when and under what conditions each BIT element (i.e. intervention component/technique/ strategy) is delivered to an individual user over time, taking into account changes in aims, elements and/or other characteristics over the course of the intervention's delivery.<br>• Optional workflow approaches include: time-based (e.g. reminder at 17h00 to walk); task-based (e.g. walk 10 000 steps per day); and event-based (e.g. lack of physical activity for two hours). The initial option is easiest. The two latter options are more challenging as they require automatic or manual user input to function effectively.<br>• Optional workflow approaches proposed in the BIT Model (Approach #7) include: conditions-based; user defined; frequency; and tunnelling. | • *Outputs:* Final (numbered) list of BCTs for the mHealth app intervention design (table of listed BCTs, their descriptions, and locations in the mHealth app's features); Conceptual (abstract rather than concrete prototype) screenshot mock-ups (with short descriptions and associated BCT numbers) of the mHealth apps interfaces and main features, highlighting where and how BCTs are operationalised and instantiated as app design features (graphical pictures).<br><br>**Step 6: Developing a Logic Model and Investigating Causal Pathways**<br>• *Aim:* Develop a logic model to describe the program theory behind/ underpinning the intervention's design, and the intended operation causal pathway flows of the intervention.<br>• *Diagram:* Logic model illustrates the causal pathway linkages between assumptions, inputs, activities, outputs, outcomes, and impact.<br>• *Logic Model Guidelines:* Use the Logic Model Development Guide (WK Kellogg Foundation, 2006) to develop the diagram.<br>• *Output:* Graphical representation of the Logic Model of the mHealth app intervention (diagram).<br><br>**Step 7: User Testing and Developing the Final App Product**<br>• *Aim:* Develop a high-fidelity working app prototype for piloting and user testing, and based on iterative prototype improvements develop a final app product.<br>• *Activities:* Develop a high-fidelity app prototype with experienced game and app developers; test the app prototypes with users in focus groups settings and real-world settings; develop a final mHealth app intervention product (for consumer market public release).<br>• *Actors:* Recommendations are made to collaborate with a mobile and smartphone app development company to rapidly and iteratively develop-test-refine the mHealth app intervention's design; measure long-term usage and engagement statistics over a period of time.<br>• Engagement can be measured in terms of flow (user attention focus and enjoyment) and usage (frequency, duration and depth of app usage).<br>• *Users:* Target user representatives interact and engage with the app prototype(s) and provide feedback on the app's feasibility, usability, user experience, acceptance, engagement, and potential effectiveness.<br>• *Output:* Prototype version(s) and associated documentation recording and logging iterative designs, refinements, user feedback findings (concrete conceptualisation); Final mHealth app intervention product (ready for consumer market app release); Record and document monitoring, usage and engagement statistics. |

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| | • The workflow can also leverage off Just-In-Time-Adaptive Interventions (JITAIs) approaches and methods. | |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main steps:**<br>• Step 1: Intervention mapping techniques and models (Approach #1); target group/population reviews and studies; reviews of literature and evidence-based empirical study findings on the health behaviour, targeted health behaviour, and the health behaviour outcomes. TUDER Checklist.<br>• Step 2: Toolbox 1 (Behavioural Theories). Intervention mapping techniques and models (Approach #1). Reviews of literature, evidence-based empirical study findings and meta-analyses to formulate a theoretical basis for the digital (or mHealth) intervention. TUDER Checklist.<br>• Step 3: Conceptual ideation (idea) of intervention design. Toolbox 2 (DHI Taxonomy). Workflow. TUDER Checklist.<br>• Step 4: Evaluation and testing methods (from both usability/UXD and behavioural science perspectives). Prototyping materials, software and techniques. TUDER Checklist.<br>• Step 4: The paper fails to discuss how prototypes can be utilised as multi-disciplinary collaborative boundary objects during the design (step 3) and refinement and evaluation (step 4) phases.<br><br>**Artefacts produced at main stages:**<br>• Step 1: Statement of Intervention Aims (target user group/population; health behaviour; targeted health behaviour; and health behaviour outcomes). Modelling diagrams (illustrating linkages and relationships) of Intervention Aims. TUDER Checklist (Category 1, Items 1 to 3).<br>• Step 2: Selected theories, model(s) and key theoretical constructs from Toolbox 1 (Behavioural Theories). Modelling diagrams (illustrating linkages and relationships) of theoretical components constituting the theoretical basis of the intervention. TUDER Checklist (Category 2, Items 4 to 6).<br>• Step 3: Selection (or set combination) of DHI Taxonomy strategies and characteristics applicable to the intervention's design. Documentation and diagrammatic illustration of the Workflow for the intervention. TUDER Checklist (Category 3, Items 7 to 9).<br>• Step 4: Results and findings from evaluation and refinement studies. Documentation on the design-evaluate-refine iteration cycles demonstrating the intervention's improvement over time. Prototype versions (produced through iteration cycles). Documented refinements to the Workflow and Intervention Design. TUDER Checklist (Category 4, Items 10 to 11). | **Artefacts utilised at main steps:**<br>• Step 1: Multi-disciplinary design team documentation and contract templates; focus group methods and techniques.<br>• Step 2: Literature reviews, meta-analyses and focus group results.<br>• Step 3: Evidence from literature reviews, meta-analyses and findings from empirical studies.<br>• Step 4: Gamification literature, meta-analyses and empirical study findings; evidence-based gamification models and taxonomies; focus group results.<br>• Step 5: CALO-RE Taxonomy; BCTT v1; evidence-based findings from literature, empirical studies and meta-analyses.<br>• Step 6: Logic model and program theory guidelines; causal pathway flows.<br>• Step 7: User testing and evaluation method guidelines. Monitoring approaches and measurement guidelines. Prototype materials, software and tools; consumer app market product development guidelines.<br><br>**Artefacts produced at main steps:**<br>• Step 1: Multi-disciplinary design team documentation, actor listings and contract agreements, consensus terminology and definitions, team protocols and collaborative work practice guidelines. Documented focus group guidelines and protocols.<br>• Step 2: Statement of Health Problem and Target Health Behaviour; Health Behaviour Determinants and Factors (list); Key User Preferences for Intervention Components (table); Key User Preferences for App Design and Appearance Features (table).<br>• Step 3: Documentation and list of selected evidence-based standards, guidelines and codes of practice (e.g. WHO recommendations for physical activity).<br>• Step 4: Gamification strategies and techniques (table and list).<br>• Step 5: Final (numbered) list of BCTs for the mHealth app intervention's design (table); conceptual graphical screenshot images (pictures) of operationalised/ instantiated BCTs as app design features.<br>• Step 6: Logic Model (and causal pathways) of the mHealth intervention (graphical diagram).<br>• Step 7: Documented user testing and evaluation findings. Prototype version(s) and associated documentation on designs, changes, refinements, edits and user feedback. Monitoring plans, measurements, strategies and statistical reports. Final mHealth app intervention product (ready for market release). |

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| 8. Knowledge boundary contribution | • The paper acknowledges the BCT Taxonomies (including v1 and CALO-RE) and PSD Principles (from the PSDM) as deriving from different philosophical worldviews, hence holding different perspectives of the shared design problem and solution space.<br>• The paper notes that although BCT Taxonomies and PSDM Principles are utilised in separate fields of study, they share commonalities and similarities, and share a common goal: to improve the design and effectiveness of digital health behaviour change intervention technologies (such as mHealth apps).<br>• An acknowledgement is made of the different interpretive flexibility of terminology utilised in different communities.<br>• Although the paper acknowledges differences in perspectives, and merges two contributions into one DHI Taxonomy, it does not provide guidance as to how different (and sometimes conflicting) interpretations, perspectives and goals can be overcome.<br>• The importance of multi- and inter-disciplinary knowledge contributions in designing effective digital (and mHealth) interventions is noted, although details regarding knowledge boundaries and processes are not covered. | • Key concepts and constructs were brainstormed and consensus was obtained on terminology at step 1. Terminology was formally documented. This enabled syntactic and semantic knowledge transfer between multi-disciplinary team members.<br>• There is value in that target user representatives are involved from an early stage of mHealth app development process, and participate early on in focus groups sessions. Focus groups with user representatives can for instance, provide insight as to whether there is preference for positive rather than negative framed messages (framed as gains rather than losses).<br>• No guidance is offered as to how knowledge boundaries can be crossed, and multi-disciplinary heterogeneous team members can be facilitated and supported when working collaboratively within shared mHealth app intervention design problem and solution spaces. |
| 9. Limitations and lessons learned | • Value in classifying PSD Principles into two parts, namely: (1) strategies, and (2) characteristics. In comparison to the BIT Model's "How" (Conceptual) and "How" (Technical), this is an alternative means of separating intervention components (i.e. strategies and BCTs) from technical instantiation characteristics pertaining to the digital or smartphone platform, respectively.<br>• Valuable in proposed integration of BCTs and PSD Principles as a (unified) DHI Taxonomy (in light of the BIT Model). A supplementary material attachment provides insight to the BCT Strategy and PSD Principle overlaps and gaps. PSD Principles corresponding to BIT Model intervention characteristics [Instantiation Component 4 – "How" (Technical) are noted (7 principles)].<br>• A limitation is noted in that the approach does not provide guidance on what combinations of DHI strategies and workflows work optimally together, or better than other combinations. Meta-analyses and literature reviews may offer insight into which DHI strategy combinations may be more effective.<br>• Another limitation is that the DHI Taxonomy is developed based on BCTT v1 and PSD Principles, and hence intervention designers and developers that are unfamiliar with either one or both may find the taxonomy challenging to use and apply.<br>• The paper is valuable in categorising health behavioural theories into (1) continuum theories (assume individual's health behaviour is caused by a set of variables such as intention and skills), and (2) stage theories (assume individual's health behaviour as progressing through a process comprising | • The approach is valuable in its proposed agile and rapid systems development approach to mHealth smartphone app development, as well as its incorporated perspective of the consumer app market and product development. These value contributions are synonymous with those provided by the Agile Development and Evaluation Approach for mHealth Apps (Approach #12).<br>• A valuable contribution and perspective is offered in the inclusion of gamification strategies and techniques. Gamification features are evidenced to demonstrate improvement in user engagement and sustained usage of apps.<br>• The approach could benefit from incorporating components of the BIT Model and BIT-Tech Model (Approach #7) which provide practical guidance for the technical instantiation of intervention components and BCTs into BIT elements and technical specifications.<br>• Although the paper emphasises and stresses the importance of forming a multi-disciplinary design team from step 1, and encourages active collaborative engagement and multi-disciplinary involvement throughout, it does not discuss details pertaining to how similarities, differences (and possible conflicts) in perspectives, goals, objectives, work practices and processes, and information are handled.<br>• Little mention is made regarding information and work practice (activity or process) communication, cooperation, coordination and negotiation.<br>• While the paper discusses and highlights the importance of health behavioural and psychology theories and developing a theoretical base for the mHealth app |

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| | several invariant stages). The paper also notes limitations of behavioural and health psychology theories.<br>• Caution is noted in the authors integration of "similarity" (PSDM: "people are more readily persuaded through systems that remind them of themselves in some meaningful way"), "liking" (PSDM: "a system that is visually attractive for its users is likely to be more persuasive") and "tailoring" (PSDM: "information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group") as falling under the same umbrella as "personalisation". "Personalisation" is also merged from the PSDM and BIT Model: [PSDM: "a system that offers personalised content or services has a greater capability for persuasion"] versus [BIT Model (Approach #7) Instantiation Component 4 – "How" (Technical): Characteristics – Bullet 4: "the altering of characteristics or content of BITs to increase relevance for individual user; e.g. machine adaptive learning"].<br>• Caution is noted in the authors encapsulating of "trustworthiness" ("a system that is viewed as trustworthy will have increased powers of persuasion"), "surface credibility" ("people make initial assessments of the system credibility based on a first-hand inspection"), "real-world feel" ("a system that highlights people or [an] organisation behind its content or services will have more credibility"), and "verifiability" ("credibility perceptions will be enhanced if a system makes it easy to verify the accuracy of site content via outside sources") under one characteristic titled "trustiness". Other PSD Principles "expertise", "authority" and "third-party endorsements", within the "system credibility support" category, are not included in the unified DHI taxonomy.<br>• While the TUDER Holistic Approach is intended to provide comprehensive guidance for the DHI and smartphone app development process, some aspects are simplistic, such as the inclusion of only a few select behavioural theories.<br>• The TUDER Approach does not recognise the difficulties in operationalising intervention strategies (i.e. BCTs) into digital software design features. The approach also fails to guide intervention designers and developers in instantiating intervention strategies into BIT elements and specific design features, and then map these to the underlying theoretical base.<br>• Notably, the TUDER Approach diagram illustrates iterations between all 4 steps, yet in the paper it fails to discuss details pertaining to these iterations. | intervention's design (step 4, 5 and 6), it does not identify or detail any particular theories or theoretical constructs.<br>• The approach is limited in that it does not consider or incorporate principles of persuasive systems design, despite focusing on the design of mHealth app interventions for health and wellness lifestyle behaviours and behaviour change.<br>• A limitation of at step 7 is the lack of guidance or recommendations for which methods, techniques, criteria or standards to use for testing and evaluating apps. Examples include the APEASE Criteria; MOST Criteria; Health-ITUEM; the Unified Theory of Acceptance and Use of Technology (UTAUT) model; RCTs; adapted RCTs; Trials of Intervention Principles (TIPs).<br>• The approach fails to consider and incorporate technological models and frameworks particularised to the mobile and smartphone app contexts, such as Just-In-Time Adaptive Intervention (JITAI) models and approaches; and the CONSORT-eHEALTH Checklist. |

## *TABLE D CONT.: THEORETICAL ANALYSIS OF MULTI- AND INTERDISCIPLINARY APPROACHES FROM AN INTEGRATIVE PERSPECTIVE*

| Integrative Perspective | | |
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| **Template Criterion** | **Approach #19** | **Approach #20** |
| 1. Multi/inter disciplinary approach number and title | **Approach #19:** Multi-Disciplinary Approach for Developing Health Promotion Behaviour Change Intervention Persuasive Technology | **Approach #20:** Behavioural Science-Informed User Experience Design (BSUED) Process for mHealth Behaviour Change Intervention Apps |
| 2. Title, author and year of literature publication | Lost in Persuasion: A Multi-Disciplinary Approach for Developing Usable, Effective, and Reproducible Persuasive Technology for Health Promotion (Blanson Henkemans, et al., 2015) | A Case Study of BSUED: Behavioural Science-Informed User Experience Design (Hekler, et al., 2011) |
| 3. Aim and summary of multi/inter disciplinary approach | The multi-disciplinary approach aims to support the iterative development of health promotion behaviour change interventions by integrating frameworks from fields of psychology, behavioural and social sciences, cognitive engineering, human factors, persuasive technology, human-computer interaction, and information systems design. It is based on two existing approaches (IM and Situated Cognitive Engineering), and comprises three main components covering themes that integrate technological features and health behaviour change strategies. It aims to provide multi-disciplinary teams with practical guidance for bridging language gaps and barriers between different disciplines. It details themes on collaborative communication and design artefacts, methods, interpretive flexibility and sound design rationales. The approach can be applied to different technology-based health behaviour change contexts. | BSUED provides an approach that integrates evidence-based health behavioural science theory and user experience design into a process for developing commercial mHealth behaviour change apps. It aims to articulate motivational frames as drivers for interventions' designs, and offers a design thinking approach to the iterative testing process. Supplementary material provides insights into the main artefact supporting cross-disciplinary motivational frame conception. BSUED was applied by King, Hekler and colleagues (2013, 2016) in the context of developing and testing three different motivationally framed physical activity behaviour change apps. Themes and subthemes detail links and translations of intervention components into mHealth app design features. |
| 4. Actors and community of practice members | • The approach emphasises the formation of a multi-disciplinary team, and consistent collaboration, communication and cooperation throughout.<br>• Actors from multi-disciplinary fields include: health psychology; human factors; health behavioural science; social science; cognitive engineering; information systems design; human-computer interaction; persuasive technology and persuasive systems design; and mobile and smartphone app design and development.<br>• The approach also involves user representatives of the at-risk target population/group for conducting evaluating testing (components 1 and 3). | • The approach recommends forming an "inter-disciplinary group", and in their mHealth app intervention context includes health promotion and health behavioural scientists; information systems designers and developers; human computer interaction and user-centred design specialists; physical activity and exercise specialists; product designers and developers; user experience designers; usability experts; smartphone app designers and developers; computer scientists; lifestyle and wellbeing management professionals.<br>• User representatives of the target population are involved during steps 3 and 5. |
| 5. Underlying theories, models and | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; Cognitive Engineering; Human Factors Engineering; Human-Centred Design; User-Centred Design (latent); User | **Perspectives:** Health Promotion; Health Psychology; Health Behavioural Sciences; Socioecological Approach; Participatory Approach; mHealth and Digital Technology Perspective; User-Centred Design (explicit); User Experience Design; Lifestyle Modification and Wellbeing Management; Consumer Smartphone App |

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| existing approaches | Experience Design; Persuasive Technology; Persuasive Systems Design; Lifestyle Modification and Wellbeing Management; Systems Thinking Approach; Human-Computer Interaction; User Interface Design; UML Modelling (Object-Orientated Analysis and Design).<br>**Individual and interpersonal theories:** Latent incorporation of some theories.<br>**Theoretical basis:** several existing approaches and theoretical models are reviewed to combine and integrate frameworks from different disciplines.<br>**Models and tools:** CALO-RE Taxonomy; BCTT v1; BCW; COM-B Model; Logic Model and Program Theory; State-of-the-Art (SOTA); Technology Readiness Level (TRL).<br>**Existing approaches:** Intervention Mapping (Approach #1); The CeHRes Roadmap (Approach #2); The situated Cognitive Engineering (sCE) Method (Neerincx, 2011); The Behavioural Intervention Technology (BIT) Model (Approach #7); Combined BIT Model and Intervention Mapping "Best of Both Worlds" (Crutzen, 2014). | Market; Product Design and Development; Human-Computer Interaction; Systems Thinking Approach; User Interface Design; Gamification.<br>**Individual and interpersonal theories:** Individual and interpersonal level theories such as SCT; SE; SLT; SS; SFT; GST.<br>**Theoretical basis:** Emphasises "theoretical rationale".<br>**Models and tools:** CALO-RE Taxonomy; Physical Activity Guidelines.<br>**Existing approaches:** No existing approaches are utilised or adapted. |
| 6. Components of the multi/ Inter-disciplinary approach | **Multi-Disciplinary Approach main components:**<br>• Component 1: Generation<br>• Component 2: Specification<br>  o Component 2.1: Specification of Intervention (Macro Level Persuasion)<br>  o Component 2.2: Specification of Interaction (Micro Level Persuasion)<br>• Component 3: Evaluation<br>  o Component 3.1: Evaluation of Interaction<br>  o Component 3.2: Evaluation of Intervention<br>**Nature of approach components:**<br>• Iterative; cyclical (feedback loops); systematic; cumulative; linear (between components 1, 2 and 3); non-linear (2.1-2.2 and 3.1-3.2); theory-based; evidence-based; collaborative; practical.<br><br>**Two Levels of Persuasion (within the Multi-Disciplinary Approach)**<br>• *Macro level persuasion:* aims at intervening on a particular target group/population to adopt healthy (lifestyle) behaviours (or behavioural modifications) as a means to improving overall health and wellbeing and quality of life.<br>• *Micro level persuasion (microsuasion):* aims to persuade (encourage or motivate) a target user to continue interacting and engaging with a digital technology device and/or software (such as a smartphone app). | **BSUED main process steps:**<br>• Step 1: Create Behavioural Science Summary Sheets<br>• Step 2: Develop Motivational Frames<br>• Step 3: Target Population Assessment and Prototype User Experience Piloting<br>• Step 4: Develop Functional Prototypes<br>• Step 5: Evaluate and Refine Functional Prototypes<br>**Nature of approach steps:**<br>• Iterative; cyclical; rapid cyclical; linear; cumulative; theory-based; evidence-based<br><br>**Step 1: Create Behavioural Science Summary Sheets**<br>• *Aim:* Create summary sheets identifying theory- and empirically- based constructs and techniques for the health behaviour change intervention.<br>• *Actors:* Health promotion and health behavioural scientists, health psychologists, physical activity and exercise specialists, lifestyle and wellbeing management professionals can contribute in creating the summary sheets.<br>• *Sources:* Evidence-based theoretical models and constructs shown to be effective in addressing a particular health behaviour; literature reviews; findings from relevant empirical studies; meta-analyses; qualitative methods such as focus groups with target user representatives.<br>• *Outputs:* Behavioural Science Summary Sheets (tables clarifying theoretical constructs, their descriptions, what each construct does, and intervention examples for applying each construct); List of selected theoretical constructs and/or techniques (BCTs). |

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| | **Component 1: Generation**<br>• *Aim:* Gather, collect and establish the building blocks (i.e. knowledge base) for the persuasive system or digital persuasive technological device. Blocks include health and operational needs, human factors and state-of-the-art.<br>• *Blocks are collected and built through:* reviewing literature and meta-analyses; epidemiological investigations (observational or literary); work process and practice analyses; qualitative research (e.g. interviews, workshops, focus groups, questionnaires).<br>• *Building blocks from the health behavioural intervention perspective:*<br>o At-risk population – the population constituting the target group intended to receive the intervention, whose members may have additional needs before, during or after an incident in functional areas.<br>o Health needs – the concerns regarding the wellbeing, quality of health and health conditions for the at-risk population, and theories thereon.<br>o Health needs assessment covers:<br>▪ The discrepancies between current wellbeing, quality of life and health conditions, and desired conditions, for the particular at-risk population.<br>▪ The environmental and behavioural causes for the health problem; performance objectives to resolve these problem(s); key determinants of behaviour associated with the performance objectives.<br>• *Building blocks from the technology perspective:*<br>o Operational demands (or operational needs) cover:<br>▪ The work and/or activity conditions for users interacting with the persuasive digital technology (device).<br>▪ The users' work characteristics, roles, tasks and contexts.<br>o Human factors – describe theory, principles, data and methods to design in order to optimise human wellbeing and overall system (or device) performance.<br>o Technological state-of-the-art (SOTA) covers:<br>▪ The current highest level of general development of a digital technology device, providing insights into which hardware and software is potentially applicable to facilitate the health behaviour change intervention's delivery.<br>▪ The technology readiness level (TRL) of the persuasive digital technology (or device) considered, which helps assess the (im)maturity of the technology (or device), and provides an indication on the investment required to fully develop the digital intervention. | • The authors suggest describing the theoretical constructs, and what each one does, in lay terms. This facilitates and supports cross boundary communication.<br><br>**Step 2: Develop Motivational Frames**<br>• *Aim:* Cluster the theoretical constructs and techniques into "motivational frames", and describe how each frame's underlying motivators intend to operate.<br>• *Actors:* Health promotion and health behavioural scientists, health psychologists, physical activity and exercise specialists, lifestyle and wellbeing management professionals can contribute.<br>• Motivational Frame – an underlying latent structure of a cluster of BCTs that taps into more fundamental processes of health behaviour change.<br>• Purpose of Motivational Frames: to identify patterns within/between constructs; to help frame the intervention's conceptual design and development; to guide the pilot testing of the theoretical constructs later on with RCTs.<br>• Examples of Motivational Frames:<br>o "Social" Frame – the underlying motivators for health behaviour change harness social and interpersonal relationships; theoretical construct examples include social support, social norms, competition, collaboration.<br>o "Cognitive" Frame – the underlying motivators for health behaviour change harness rational thought processing to guide the user towards a logical conclusion/outcome; theoretical construct examples include problem-solving, cost-benefit analysis, goal setting, action planning.<br>o "Emotional" Frame – the underlying motivators promote health behaviour change by leveraging the user's emotions and positive feeling experiences; theoretical construct examples stem from operant conditioning (SLT) and gamification, including positive reinforcement, positive behaviour-positive reward pairing, immediate praise feedback, enjoyment, and fun.<br>• *Objects:*<br>o Develop a Motivational Frames report (document), describing the underlying latent structure for each, and clearly detailing the characteristics for each motivational frame.<br><br>**Step 3: Target Population Assessment and Prototype User Experience Piloting**<br>• *Aim:* Iteratively assess, design, develop and pilot test low-fidelity prototypes for each motivational frame with user representatives of the target population.<br>• *Actors:* Involves all multi-disciplinary team members working together, with user experience designers, usability experts, and information systems designers and developers taking the lead on ideation and design-refine concept realisation.<br>• *Activities:* |

**Component 2: Specification**

- *Aim:* Set the specifications for the intervention (at the macro level persuasion) and the interaction (at the micro level persuasion) based on the generated building blocks (from component 1).
- Specifications are important to clarify to ensure the technology (or digital device) is designed and programmed as intended (by designers/developers), and aims to specify the change objectives, selected BCTs, and a description of the strategy(ies) for both the intervention and interaction.
- Change objectives – the most immediate target of an intervention or interaction that will best address the health behaviour and interaction challenge(s) identified, respectively.
- Determinants – evidence-based factors (or influences) that have demonstrated association with performance of the targeted health behaviour, particularly for the given target at-risk population.
- Change objective matrix(ces) – combine performance objectives (to resolve health problem(s)) with selected (important) determinants of behaviour.
- Scenario – a description of users, background information on the users, and assumptions about the users' contexts, goals and objectives, and the sequences of actions and events.
- Design scenario – a short storyline (paragraph) describing how a user or persona can use the technology (or device) with a few details.
- (Theory-based) design rationale – the (intervention and interaction) arguments, motivations and reasons behind decisions made regarding the design of a technology (or device).
- Use cases – provide a sequence of interactions between multiple roles or users, are situated (given a particular circumstance, context or activity) and the format of use case narrative templates include the: goal; actor(s); pre-conditions; post-conditions; action sequences; and requirements.
- Requirements – a functionality or capability that the technology (or device) needs to be able to perform, address or satisfy; they describe succinctly what the technology (or device) needs to do in concrete observable effects.
- Claim – refers to an intended (or adverse side) effect from using a particular functionality (or feature) of the technology (or device); described in the functional requirements.

- **Component 2.1: Specification of Intervention**
  - *Aim:* Specify the performance objectives, determinants (theory), and change objectives; map change objectives to BCTs (or theory) and intervention strategies (practical applications); create design scenarios; specify requirements and claims.
  - Conduct needs finding assessments with representatives of the target user group/population to understand their health behaviour(s) and motivations for health and health behaviour(s).
  - Perform iterative brainstorming and user experience design cycles to develop several conceptualisations (ideations) for each frame (based on their theoretical constructs and underlying motivators.
  - Narrow the conceptualisations to a few options and develop low-fidelity prototypes for each frame (materials include paper, mock-ups, sketches).
  - Conduct iterative design-test-refine cycles with target users to elicit feedback on all of the low-fidelity prototype frames.
  - Based on the iterative brainstorming and user experience design feedback cycles (and in considering the theoretical constructs, BCTs and motivational frames), further narrow down the low-fidelity prototype options for all of the frames (approximately 4 prototype concepts per frame).
- *Outputs:*
  - Target Population Needs Assessment report.
  - Prototype User Experience Design Piloting report – documenting iterative brainstorming and user feedback cycles for each motivational frame, detailing the user-centred design, usability and user experience design parameters for each of the smartphone app motivational frames.
  - A few (approximately 4) low-fidelity prototypes for each motivational frame, ready for functional prototype development.

**Step 4: Develop Functional Prototypes**

- *Aim:* Develop one functional prototype for each of the motivational frames, to evaluate in trial testing.
- *Actors:* Information systems designers and developers, user experience designers, usability experts, mobile and smartphone app designers and developers, computer scientists.
- *Activities:* Develop one functional prototype for each motivational frame based on the low-fidelity prototypes (outputs of step 3); harness existing technologies and methods to incorporate into the app's features to functionalise the motivational frames (e.g. accelerometers, GPS, push notifications, social networking links); follow smartphone operating system (OS) guidelines (e.g. Android and Apple).
- *Outputs:*
  - One functional prototype for each motivational frame, ready for trial evaluation testing.

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| | ○ *Activities:* Select BCTs from the CALO-RE Taxonomy, the BCTT v1, and other theoretical models or constructs (such as the ASM Model, the Zone of Proximal Development, and Social Penetration Theory). Create design scenarios. Translate design scenarios into a requirements and claims specification.<br>○ *Outputs:*<br>▪ Change Objective Matrix for Intervention [table on performance objective, determinants (theory), change objective].<br>▪ Mapping Matrix of BCTs to Change Objectives and Intervention Strategy Descriptions [table on change objectives, BCTs (or a theory/ theoretical constructs), strategy (practical application descriptions for each BCT)].<br>▪ Create Design Scenarios (short storyline summary paragraphs).<br>▪ Requirements and Claims Specification (describe requirements in terms of a strategy, and list functional, hardware (technical), and software (interface) requirements, and articulate claims). Strategic requirements contribute to intervention details (macro level persuasion).<br>▪ Theory-Based Design Rationale of the Intervention (report).<br><br>• **Component 2.2: Specification of Interaction**<br>○ *Aim:* Specify the performance objectives, determinants (theory), and change objectives; map change objectives to BCTs (or theory) and interactions strategies (practical applications); create design scenarios; create use cases; specify requirements and claims.<br>○ *Activities:* Select BCTs or (interaction) change techniques from the CALO-RE Taxonomy, the BCTT v1, and other theoretical models or constructs (such as the ASM Model, the Zone of Proximal Development, and Social Penetration Theory). Create design scenarios. Employ use case modelling diagramming techniques and narrative templates to guide the translation of design scenarios to generic situated use cases. Translate scenarios into a requirements and claims specification.<br>○ *Outputs:*<br>▪ Change Objective Matrix for Interaction (table on performance objective, determinants (theory), change objective).<br>▪ Mapping Matrix of BCTs to Change Objectives and Intervention Strategy Descriptions [table on change objectives, BCTs (or a theory/theoretical constructs), interaction strategies (practical application descriptions for each BCT)].<br>▪ Create Design Scenarios (short storyline summary paragraphs). | **Step 5: Evaluate and Refine Functional Prototypes**<br>• *Aim:* Evaluate the functional prototypes by running usability and trial studies on all of them in tandem, and refine based on results.<br>• *Actors:* Involves all multi-disciplinary team members working together, with user experience designers, usability experts, and information systems designers and developers taking the lead on usability evaluation testing, and health promotion and health behavioural scientists and health psychologists taking the lead on trial evaluation testing.<br>• *Usability evaluation measures:* functional prototype smartphone app usage, feasibility, acceptance, engagement, user satisfaction<br>• *Trial evaluation measures:* clinical trial outcome measures including health behavioural changes, anthropomorphic changes (e.g. BMI, weight), adherence and motivational frame (i.e. intervention) effectiveness.<br>• *Methods:*<br>○ Usability, UCD and UXD studies – covered over an 8-week period (with a large sample of target user representatives, approximately 100 participants).<br>▪ Conduct qualitative and quantitative analyses on the usability, user-centred design and user experience design results to determine which motivational frame demonstrates the most potential with users.<br>▪ Methods can include semi-structured interviews, walk-throughs, simulations, questionnaires.<br>▪ Example study with physical activity smartphone apps published in King, et al. (2013).<br>○ RCTs – covered over an 8-week period (with a large sample of target user representatives, approximately 100 participants).<br>▪ Conduct quantitative statistical analyses on the RCT results to determine which motivational frame demonstrates the highest effectiveness measure.<br>▪ Example study with physical activity smartphone apps published in King, et al. (2016).<br>• *Motivational Frame Decision Point:* decide, as a multi-disciplinary team, which motivational frame (approach to intervention delivery) demonstrates the most effective potential.<br>• *Refinement:* Based on the usability, UCD and UXD results and the clinical trial evaluation results, refine and improve the design and development of the Final Smartphone App Prototype.<br>• *Outputs:*<br>○ Evaluation report – documenting the evaluation processes of the functional prototypes and the usability and trial results.<br>○ Refinement Specification – detailing the final refinements and improvements to the design and development of the one chosen motivational frame. |

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| | ▪ Use Case Diagrams and Narratives (based on the design scenarios, guided by a template).<br>▪ Requirements and Claims Specification (describe requirements in terms of a strategy, and list functional, hardware (technical), and software (interface) requirements, and articulate claims). Functional, hardware and software requirements contribute to interaction details (micro level persuasion; microsuasion).<br>▪ Theory-Based Design Rationale of the Interaction (report).<br><br>**Component 3: Evaluation**<br>• *Aim:* Using the Logic Model, state the intervention and interaction (positive and negative) outcome effects based on claims and requirements; conduct evaluations to validate claims, and utilise results and findings to further optimise and improve the development decisions made (in component 2).<br>• Logic Model – derived from Intervention Mapping (Approach #1) describes the intervention resources, inputs, activities, outputs, audiences, and short-, intermediate- and long-term outcomes related to a specific health (and health behavioural) problem and situation. The model allows for the back-tracking through the specifications to identify and measure critical measures of performance, and validate claims.<br>• Claims:<br>o A claim – refers to an intended (or adverse side) effect from using a particular functionality (or feature) of the technology (or device), and are described in the functional requirements.<br>o Claims – state the hypothetical outcomes (effects and impacts) that result from the fulfilment of intervention and interaction change objectives; justify the inclusion of particular requirements in terms of expected (hypothesised) effects within certain contexts (use cases); state the expected effect and highlight trade-offs between the advantages and disadvantages of related requirements.<br>o Claims – are validated through process evaluation (at the interaction level) and effect and impact evaluation (at the intervention level).<br><br>• **Component 3.1: Evaluation of Interaction**<br>o *Aim:* Evaluate the interaction of the technology (or device) through process evaluation.<br>o Process evaluation – evaluation(s) designed to establish whether the interaction is feasible and usable; if the technology (or device) is representable; and what the anticipated effectiveness (effective potential) will be of the technology (or device) once fully developed. | o A final prototype (of the one chosen motivational frame option). |

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| | o *Methods (aiming to validate interaction related claims):* user experience testing; usability testing; simulations; prototype testing; human-in-the-loop testing; expert interviews, focus groups, surveys, questionnaires, prototype or mock-up run-throughs; end-user interviews, focus groups, surveys, questionnaires, prototype or mock-up run-throughs.<br>o *Evaluation feedback:* is used to iteratively refine and improve the interaction design of the technology (or device) at the micro level of persuasion (microsuasion).<br>o *Outputs:*<br>▪ Effect Scorecard: Claims about the Interaction (Micro Level Persuasion; Microsuasion) stating the effect, positive outcome(s), and negative outcome(s).<br>▪ Interaction evaluation study results, findings and reporting.<br><br>• **Component 3.2: Evaluation of Intervention**<br>o *Aim:* Evaluate the intervention through effect and impact evaluation.<br>o Effect and impact evaluation – evaluation(s) designer to assess, measure and determine whether the intervention is/is not working as intended.<br>o *Methods (aiming to validate intervention related claims):* RCTs, quasi-experimental design trials.<br>o *Evaluation feedback:* measures are used to iteratively refine and improve the intervention's design and provide guidance on scaling up at the macro level of persuasion; measures relate to effects (quality of life, health and wellbeing; behavioural change, anthropomorphic measures) outcomes, impacts, and observed and analysed determinants.<br>o *Outputs:*<br>▪ Effect Scorecard: Claims about the Intervention (Macro Level Persuasion; Microsuasion) stating the effect, positive outcome(s), and negative outcome(s).<br>▪ Intervention evaluation study results, findings and reporting. | |
| 7. Design artefacts, boundary objects and supporting methods | **Artefacts utilised at main components:**<br>• Component 1: Building blocks [literature reviews and meta-analyses; epidemiological studies; work process and practice analyses; qualitative research (e.g. interviews, workshops, focus groups, questionnaires)].<br>• Component 1: Templates and guidelines for creating: at-risk population report; health needs and assessment report; operational demands (or needs) report; human factors report; SOTA and TRL report.<br>• Component 2: Templates and guidelines for creating the intervention and interaction specifications: Change Objective Matrix(ces); Mapping | **Artefacts utilised at main steps:**<br>• Step 1: Behavioural Science Summary Sheets template; findings from literature, meta-analyses and empirical studies on theories and theoretical constructs, and change techniques; CALO-RE Taxonomy.<br>• Step 2: Behavioural Science Summary Sheets and List (outputs from step 1); further literature and empirical reviews.<br>• Step 3: Motivational Frames report (output from step 2); Target Population Needs Assessment template; Methods, techniques and guidelines for low-fidelity |

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| | Matrix(ces); Design Scenarios; UML Modelling (UC Diagrams and Narratives); Requirements and Claims Specification; Theory-Based Design Rationale.<br>• Component 2: Tools utilised: CALO-RE Taxonomy; BCTT v1; relevant psychological theoretical models and theoretical constructs (for techniques).<br>• Component 3: Methods, techniques and guidelines (including ethics) for process evaluations of the interaction, and effect and impact evaluations of the intervention; Scorecard template.<br><br>**Artefacts produced at main components:**<br>• Component 1: Documented building blocks.<br>• Component 1: Reports on: at-risk population; health needs and assessment; operational demands (or needs); human factors; SOTA and TRL.<br>• Component 2: Intervention and Interaction Specifications Documentation: Change Objective Matrix(ces); Mapping Matrix(ces); Design Scenarios; Use Case Diagrams and Narratives; Requirements and Claims Specification; Theory-Based Design Rationale.<br>• Component 3: Effect Scorecards (for intervention and interaction). Documented ethical procedures and evaluation study results, analyses and findings. Process Evaluation Report (on interaction – micro level persuasion; microsuasion); Effect and Impact Evaluation Report (on intervention – macro level persuasion).<br><br>**Boundary Objects for Multi-Disciplinary Team Collaboration, Communication and Cooperation (for design and knowledge boundary crossing):**<br>• Glossary – common language (terminology and definitions)<br>• Concept map – common ideation and design for the macro and micro levels.<br>• Shared ontology – common taxonomies for cross disciplinary team work.<br>• Scenarios and design scenarios – common conceptualisation and graphical representations of the intervention and its interactions with users. | prototyping, brainstorming sessions, and iterative rapid UXD feedback cycle sessions.<br>• Step 4: Low-Fidelity Prototypes of the few motivational frames (output from step 3); Methods, guidelines and software for designing and developing a functional prototype.<br>• Step 5: Functional Prototype (output from step 4); Methods, techniques, guidelines and ethical protocols for conducting usability, UCD and UXD studies, and the RCT trails; Participant Samples (based on valid sampling methods).<br><br>**Artefacts produced at main steps:**<br>• Step 1: List of selected theoretical constructs (list); Behavioural Science Summary Sheets (tables).<br>• Step 2: Motivational Frames report (describing the underlying latent structure for each motivational frame).<br>• Step 3: Target Population Needs Assessment report; Prototype User Experience Design Piloting report; Motivational Frame Low-Fidelity Prototypes (a few for each motivational frame).<br>• Step 4: One Functional Prototype (for each motivational frame).<br>• Step 5: Evaluation report; Refinement Specification; Final Prototype (of selected motivational frame). |
| 8. Knowledge boundary contribution | • The multi-disciplinary approach recognises and aims to address "language barriers between developers from different disciplines". The paper notes that when working together, challenges may be faced as heterogeneous developers (actors) often "speak different jargons when it comes to development [which] can lead to misunderstandings". The proposed multi-disciplinary approach therefore aims to "bridge the language gap between different fields involved".<br>• The approach emphasises the creation and consistent systematic use of a "*lingua franca*" between heterogeneous multi-disciplinary team members, to | • The approach aims to bridge the divide between the health behavioural science and user experience design disciplines, and integrates their distinct, yet relevant, knowledge into a behavioural science-informed user experience design (BSUED) process.<br>• The integrative approach highlights the need for a mutli- and inter-disciplinary team working together, although the paper fails to discuss how communication, collaboration and cooperation can operate when crossing knowledge boundaries, |

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| | improve communication and collaboration during the development process. A "*lingua franca*" represents a common language operating at the syntactic knowledge level, supporting and facilitating knowledge transfer across knowledge boundaries (and between different disciplines). Syntactic knowledge boundary objects include: a consensus glossary (terminology and associated definitions explicating and illustrating different components); a common concept map; a shared ontology (for reuse during the process).<br>• The approach aims to draw out implicit knowledge held by multi-disciplinary heterogeneous, albeit relevant and important, contributing parties. Design work is often informed by past experiences, implicit expertise and skills, and heuristics.<br>• Scenarios and design scenarios (in components 2.1 and 2.2) are identified as valuable interactive boundary objects (design artefacts) for describing and drawing communal conceptualisations or pictures of how the technology (or device) should work with users (or personas) to achieve the specified health behavioural intervention objectives. | and fails to identify boundary objects that can support and facilitate knowledge transfer, translation and transformation.<br>• The Behavioural Science Summary Sheets may provide a material artefact starting point for supporting communication between health behavioural scientists and specialists from the technological perspective; to tangibly work together, expanding the summary sheets to incorporate the technical design and development specifications for the operationalisation and realisation of the motivational frames. These forms would then be similar to the knowledge objects (e.g. tabularised outputs) discussed in other approaches (e.g. Approaches #5, #7, #8, #9, #17, #18). |
| 9. Limitations and lessons learned | • The multi-disciplinary approach is valuable in its breaking down and distinguishing between "macro level persuasion" and "micro level persuasion" in the context of digital health behaviour change.<br>• The paper emphasises a valuable point: persuasive systems design does matter when developing effective digitally delivered health behaviour change interventions such as smartphone mHealth apps. This notion reiterates what other prominent digital health behaviour change authors have argued in the multi-disciplinary field (Kelders, et al., 2012).<br>• The multi-disciplinary approach offers an alternative perspective that has not yet been reviewed: situated Cognitive Engineering (sCE). sCE is a framework for developing cognitive systems, i.e. personal, adaptive and intelligent systems intended to support human performance in close collaboration with contextualised complex and dynamic task environments. The integration of a sCE method provides a process for generating, specifying, evaluating and refining cognitive functions for a particular digital technology. By including these cognitive functions, the adaptive nature of humans and technology, and their reciprocal dependencies, are addressed.<br>• The approach offers a valuable contribution by considering SOTA and TRL, which aim to assess the highest general level of development and state of readiness level of a persuasive technology (or device), respectively.<br>• The multi-disciplinary approach offers a lesson in its incorporation of other change techniques (and cognitive, social and behavioural theories) in addition to the commonly referenced CALO-RE Taxonomy and BCTT v1 techniques. | • A notable limitation of the approach is that it only conducts target user needs assessments in step 3, to understand their health behaviour(s) and motivations for health and health behaviour(s) in relation to the iterative prototype user experience design piloting cycles. This is a weakness in comparison to the majority of other approaches reviewed that conduct target population and user needs assessments from step 1. Conducting user needs assessments post steps 1 (Create Behavioural Science Summary Sheets) and 2 (Step 2: Develop Motivational Frames) is risky as user feedback from step 3 may not align (and may even conflict) with investigative findings and decisions made in steps 1 and 2. This will then waste time and resources, as the multi-disciplinary team will need to revise and redirect the outputs from steps 1 and 2.<br>• The approach is limited in that it does not always provide sufficient detail at each step. For instance, no practical guidance is provided for translating and clustering theories, theoretical constructs and techniques (BCTs) into motivational frames, and no practical guidelines are provided for translating motivational frames into low- and high-fidelity prototypes.<br>• The lack of practical guidance (prior point) reveals another limitation of the approach: it requires experienced contributing team members. Translating theoretical constructs and techniques into motivational frames, for example, would require a substantial background of experience and understanding, placing heavy responsibility on the health behavioural science professionals.<br>• Similarly, operationalising motivational frames into app design features requires expertise and skills from experienced designers and developers from information |

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| | Examples: The Abnormal Situation Management (ASM) Model; The Zone of Proximal Development (Vygotsky); Social Penetration Theory.<br>• The theoretically-grounded value sensitive design (VSD) method is suggested to further involve end users (and their human values).<br>• The approach is limited in that it fails to consider business, healthcare and consumer app market ecosystems, which would require investigations into details such as infrastructure, consumers, finances from an early stage.<br>• The approach can benefit from Just-In-Time-Adaptive Interventions (JITAIs). | systems, mobile and smartphone app development, usability studies, UCD, and UXD. It further assumes that these designers and developers (from the technological perspective) are able to interpret, understand and pragmatically operate health behavioural science knowledge (e.g. BCTs).<br>• Step 2 is limited in that it primarily draws from the CALO-RE Taxonomy and does not use the latest BCTT v1 offering a 93 technique list.<br>• The rapid iterative design-test-refine cycles can benefit from employing a Design Thinking approach.<br>• The approach can benefit from Just-In-Time-Adaptive Interventions (JITAIs).<br>• More recently proposed evaluation tools (and reporting guidelines) were not leveraged. Examples of these include: APEASE Criteria; MOST Criteria; Health-ITUEM; the Unified Theory of Acceptance and Use of Technology (UTAUT) model; adapted RCTs; and Trials of Intervention Principles (TIPs); the MARS Rating Scale; incremental and fractional factorial experiment testing; and CONSORT-eHEALTH. |

# Appendix I (Chapter 6): A Critical Analysis of Approaches

## 6.4 Critical Theoretical Analysis of Multi- and Interdisciplinary Approaches

The template criteria (Table 6.5) provides a lens for conducting the critical thematic and comparative theoretical analysis on the twenty selected multi- and interdisciplinary digital health intervention development approaches (Table 6.6) across the four perspective categories (Figure 6.4). The hybrid cognitive reasoning strategy, along with disciplined imagination, thought trials, sensory perceptions, cognitive sensemaking, creativity, plausibility judgements and trial-and-error imaginary (mental) experimentation, is applied to identify, critically analyse and organise themes and subthemes relevant to the proposed boundary object view and intended interdisciplinary framework artefact (Chapter 7).

To conduct the critical thematic and comparative theoretical analysis, the six-step process was applied (Table 6.3). To briefly describe the key aspects of the process, firstly, the twenty selected multi- and interdisciplinary approaches were carefully read and re-read, and colour-coded highlights and notes were made, to enhance the researcher's familiarity with each literature publication and approach contribution. Secondly, the researcher meticulously reviewed, summarised and critically analysed each multi- and interdisciplinary approach according to the nine criteria in the template (Table 6.5). Four detailed A3 tables spanning 75 pages, organised by perspective category (Tables A, B, C and D, respectively), were produced during this meticulous process (Appendix H). Thereafter (thirdly), the researcher deeply immersed themselves in Appendix I, and performed critical cross comparisons of all potential themes, subthemes and theme relationships for the approaches within each of the four categories. The findings were then written up and reported in Sections 6.4.1 to 6.4.4.

Sections 6.4.1 to 6.4.4 provide the critical thematic and comparative theoretical analysis findings on the multi- and interdisciplinary approaches. The findings are divided in accordance with the four categories, namely the *Health Sciences*, *Information Systems and Technology*, *Partnership*, and *Integrative* perspectives, respectively. The findings are presented and discussed in terms of seven main themes (seven sub-headings), based on the template criteria (Table 6.5). The seven main themes cover the: (1) *aims and contexts*; (2) *actors and community*

*of practice members*; (3) *perspectives, underlying theories, models, tools and existing approaches*; (4) *nature of the processes and process steps and activities*; (5) *any design artefacts, boundary objects and supporting methods employed at each process step*; (6) *knowledge boundary contributions*; and (7) *noteworthy limitations and lessons learned*.

### 6.4.1 A Critical Analysis of Multi- and Interdisciplinary Approaches: A Health Sciences Perspective

Multi- and interdisciplinary approaches offering a predominant health sciences perspective are imperative to review and critically analyse because they provide insight into the health context, particularly the health promotion and health behaviour change intervention landscapes, which informs the foundation for designing, developing and evaluating digital health interventions. The Health Sciences Perspective category specifically consists of approaches intended for: general health promotion interventions and programmes (Approach #1); generic health information systems such as eHealth systems and technologies (Approach #2); general complex health interventions (Approach #3); general public health interventions (Approach #4); and digital health behavioural change interventions targeting physical activity in particular (Approach #5). Overall, the five health sciences approaches provide insight into the main themes and subthemes that are essential and fundamental to the health intervention context.

The template criteria (Table 6.5) is used to critically analyse each of the five approaches. Table A in Appendix H provides a full detailed summary analysis of the health science approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the five approaches, presented in a written report discussion. Box 6.4 identifies the five multi- and interdisciplinary approaches classified in the Health Sciences Perspective.

- **Approach #1** The Intervention Mapping (IM) Approach for Health Promotion Programmes
- **Approach #2** The Holistic Approach to eHealth Technology Development: The CeHRes Roadmap
- **Approach #3** MCR Guidance for Developing, Evaluating and Implementing Complex Health Interventions
- **Approach #4** Six Steps for Quality Health Intervention Development (6SQuID)
- **Approach #5** IM and the BIT Framework for Developing a mHealth Physical Activity and Sedentary Behaviour Change App

*Box 6.4: Multi- and Interdisciplinary Approaches: Health Science Perspective*

*[Source: Researcher's own construction]*

#### 6.4.1.1 Aims and Contexts of Health Science Perspective Approaches

The five multi- and interdisciplinary approaches categorised in the Health Sciences Perspective share a common aim: *to guide intervention designers and developers through a process, comprising a series of steps (also referred to as stages, phases or components), that ultimately yields the production of health interventions that are either generic (non-technological) or systems-/digitally-based (technological)*. Approaches #1, #3 and #4 aim to provide a process for developing health interventions in general, intended for delivery through various modes and platforms. Approaches #2 and #5, in comparison, aim to provide a process for developing health interventions delivered through digital and technological platforms. Out of the five approaches, only Approach #5 is aimed at guiding the design of behaviour change interventions intended for delivery via mobile devices and apps in particular. Moreover, Approach #5 is the only approach in the critical analysis that specifically targets physical activity behaviour change. Notably though, the other four approaches (#1, #2, #3 and #4) have been employed, adapted and applied to both the mHealth app and physical activity behaviour change intervention contexts in a range of studies; for example, Brug, Oenema and Ferreira (2005), Matthews, et al. (2017), Middelweerd, et al. (2018) and Simons, et al. (2018).

In terms of target audience, all five approaches have been employed for informing the design, development and evaluation of health interventions across one or more socioecological levels of health promotion and NCD prevention, and have been used specifically for targeting the individual and interpersonal socioecological levels. Overall, all five of the approaches aim to support multi- and interdisciplinary collaborative team involvement, provide theory and evidence-based processes, and rely on methods, artefacts and objects to support teams' collaborative efforts. Furthermore, all five approaches aim to harness and/or draw from existing theoretical models, although only three of the five approaches (Approaches #3, #4 and #5) aim to provide health intervention development guidance based on existing approaches. Approach #5, for instance, is based on an integration of *Intervention Mapping* and *The Behavioural Intervention Technology (BIT) Model*, namely Approaches #1 and #7, respectively.

For purposes of length, the Health Sciences Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.1.2 to 6.4.1.7 are extracted to Appendix I. One summary table and two summary figures for the Health Sciences Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

#### 6.4.1.2 Actors and Community of Practice Members

A heterogeneity of actors and community of practice members are emphasised by all five multi- and interdisciplinary approaches in the Health Sciences Perspective category. Four of the approaches, with the exception of Approach #5, refer to participating actors as "stakeholders" and "practitioners". Approaches #1, #2 and #4 directly discuss third-party stakeholder involvement in the decision-making and intervention development process, while Approach #3 indirectly refers to third-party practitioners, and Approach #5 does not cover third-party team member involvement. Third-party stakeholders include government officials, project funding investors and payers, purchasers, media, legislative parties, insurance companies, and public health and program intervention policy makers. All five approaches explicitly and latently refer to the participatory involvement of academic institutions and research groups or researchers, denoting the importance of bridging divides and discrepancies between research and practice, and intervention theory and real-world practical intervention implementation. In terms of team formalities, none of the approaches discuss the mutual and formal development and signing of team contract agreements, although Approach #1 does briefly mention contract agreements and Approach #2 mentions the desire for a mutual agreement on the objectives of a given digital health intervention programme. Approach #2, further highlights issues regarding the frequent lack of well-defined powers, roles and responsibilities during the initiation stage of multi- and interdisciplinary health intervention development projects. Only one of the five approaches, specifically Approach #1, outlines an insightful list of questions to guide the recruitment of stakeholders for a multi- and interdisciplinary team. Example questions include "Who has the content knowledge relative to the health problem or its causes?" and "Who is well respected for knowledge of this health problem or ones like it?".

Some approaches (Approaches #1, #2 and #5) employ the terms "intervention designers" and "intervention developers" to describe the key actors and community of practice members in a given multi- and interdisciplinary intervention development team. Approach #2 also uses the term "developers" to describe technical professionals and technology specialists, suggesting an allusion to computer science and programming knowledge and expertise. Two of the five approaches, namely Approaches #1 and #2, discuss the involvement and roles of health intervention project initiators, managers and leaders, who hold responsibilities in the continuity and success of the project, and who oversee (that is, organise, facilitate and coordinate) multi- and interdisciplinary team collaboration efforts. All five approaches make reference to professional actors and disciplinary experts who are able to contribute a heterogeneity of

specialist knowledge, skills and expertise to the digital health intervention development process. Approaches #1, #2 and #3 make reference to healthcare and health related professionals. With regard to mentioning specific actors with particular disciplinary expert knowledge and skills, Approach #1 identifies multi- and interdisciplinary team members to include: project leaders; planning group/team; technical specialists; creative consultants (graphic designers, photographers, designers, illustrators); materials developer; health psychologists; health behavioural change specialists; health intervention programme developers; and various knowledge expert consultants. Approach #2 identifies team members to include: healthcare professionals; investors; patients; clinicians; information technology providers; informal caregivers; health service researchers; healthcare organisations; information systems designers and developers; purchasers; consumers; policy makers; practitioners; researchers; administrative developers; user-centred designers; legal scientists; epidemiologists; social scientists; and eHealth technology developers. Approach #3 only mentions a few actors: health behavioural scientists; researchers; healthcare professionals; and clinicians. Approach #4 identifies: researchers; practitioners; public health practitioners; policy makers; practice developers. Approach #5 makes no reference to a multi- and interdisciplinary team per se, but mentions a few team actors: health behavioural intervention developers; behavioural scientists; and intervention designers; and latently discusses the involvement of mHealth app designers and developers throughout the article.

For all five of the multi- and interdisciplinary approaches explicit references are made to target population (end user) representatives as participants involved in various specific, or all, stages of the design, development and evaluation process. Approach #1, however, also considers intervention adopters, implementers and maintainers as "users" of health programmes. Target user representatives generally refer to individuals who are willing to directly or indirectly participate in, and contribute to, the conceptual planning, design, development, and evaluation of a health intervention. Indirect participation, for example, would describe users' feedback during piloting and evaluation studies on low- and high-fidelity mHealth intervention app prototypes, which would then be analysed and potentially incorporated in a subsequent (improved) prototype version based on the intervention developers' discretion. Direct participation, in comparison, would refer to active engagements and contributions from participants, who themselves, would be involved in the redesigning and refining of a specific mHealth intervention app prototype. This latter target user participant involvement traverses into participatory design research methods which falls under the third Partnership Perspective

category. The type of participant involvement in the five Health Sciences multi- and interdisciplinary approaches describe a more indirect, rather than direct, form.

#### 6.4.1.3 Perspectives, Underlying Theories, Models, Tools and Existing Approaches

All five multi- and interdisciplinary approaches in the Health Sciences Perspective category adopt a health promotion and socioecological approach perspective to health intervention development. The field of health psychology also underpins and informs all five approaches. Approaches #1, #3 and #4 are orientated towards public health interventions, which incorporates, yet surpasses, the individual and interpersonal socioecological levels of health promotion intervention by involving community, organisational, political, legislative and possibly even supranational (global) parties. Approach #5, in comparison to the other four approaches, specifically targets the dual intra-inter(primary)personal socioecological levels of health promotion behaviour change intervention development. All five approaches incorporate participatory approach perspectives, which essentially encourage collaborative cooperation between multi- and interdisciplinary actors and aim for participative decision-making. Approach #2 is different to the other four approaches in that it incorporates a business modelling approach and perspective to eHealth technology development. Approaches #1, #2 and #5 integrate systems thinking approaches which consider the complex dynamic interrelationships between components of an intervention and its targeted application context, and which seek to understand how various interdependent parts function together as a whole. A systems thinking perspective to health promotion intervention design is valuable for two main reasons. Firstly, it recognises that changing individuals' health behaviour is a multi-dimensional and complex task, and that it involves the targeting of multiple determinants and change mechanisms. Secondly, systems thinking complements the technological focus of this study since it recognises and considers that the adoption and utilisation of digital health interventions is dependent on the targeted user populations and the situated contexts-of-use; essentially adding to the wickedness of the shared multi- and interdisciplinary problem and solution space. Associated with the systems thinking perspective, Approach #2 incorporates perspectives of systems engineering and software engineering. The other three approaches do not discuss either type of engineering approach. The design thinking perspective was not mentioned in any of the five multi- and interdisciplinary approaches. Four of the approaches (Approaches #1, #2, #3 and #5) incorporate aspects of the user-centred design approach, while one approach (Approach #2) incorporates the human-centred design approach as a grounding

principle of eHealth technology development. In comparison, Approach #4 does not integrate either the user-centred design or the human-centred design approaches. User interface design is recognised and discussed in Approaches #2 (latently) and #5 (explicitly), yet is not acknowledged in Approaches #1, #3 and #4. User experience design is not discussed in any of the five approaches. Approach #2 is dissimilar to the other approaches in that it incorporates perspectives and approaches from persuasive technology and persuasive systems design. In contrast to the other four multi- and interdisciplinary approaches, Approach #5 is the only approach that adopts a digital mHealth technology perspective and acknowledges the commercial smartphone app industry and the consumer app market. Moreover, Approach #5 is the only approach that focuses on healthy lifestyle (behaviour) modification and wellbeing management, and more precisely on sport science and exercise promotion, as well as physical activity behaviour change in particular.

In terms of the theoretical bases underpinning the five multi- and interdisciplinary approaches reviewed in the Health Sciences Perspective category, Approach #2 is based on and informed by a critical analysis of sixteen existing eHealth technology frameworks, and Approach #4 is based on and informed by a critical review of five existing (non-technological) public health intervention development approaches. With regard to individual and interpersonal psychological theories, Approaches #1, #3 and #5 mention a few well-known theories, theoretical constructs and models that are frequently cited and discussed in health psychology and health promotion intervention research (Glanz, Rimer and Viswanath, 2008; Davis, et al., 2015; Kwasnicka, et al., 2016; Hagger and Weed, 2019), and particularly in physical activity behaviour change intervention studies (Buchan, et al., 2012; Rhodes, McEwan and Rebar, 2019). Some of the theories discussed include: social cognitive theory (SCT); self-determination theory (SDT); self-regulation theory (SRT); self-identity theory (SIT); self-efficacy theory (SET); social learning theory (SLT); theory of reasoned action (TRA); theory of planned behaviour (TPB); goal setting theory (GST); protection motivation theory (PMT); theories of automatic behaviour and habit formation; the transtheoretical model (TTM); the health belief model (HBM); the diffusion of innovations technology model (DIT); the elaboration likelihood model (ELM); the integrated behaviour change model (IBCM); and the precaution adoption process model (PAPM). For the exact identification of which individual and interpersonal theories are identified in Approaches #1, #3 and #5, refer to Table A in Appendix H. Notably though, Approach #5 is the only approach of the five reviewed that

identifies and integrates theory on just-in-time adaptive interventions, which is valuable for the mHealth intervention and smartphone app contexts.

Theory-informed and evidence-based (health) models and tools play an integral role in assisting intervention designers and developers when developing health promotion behaviour change interventions. Four of the approaches, namely Approaches #1, #2, #3 and #5, identify two coding taxonomies: the CALO-RE Taxonomy (Coventry, Aberdeen, and London – Refined Taxonomy), and the BCTT v1 (Behaviour Change Technique Taxonomy Version 1). Approaches #1 and #5 also acknowledge and utilise a taxonomy for development: the Taxonomy of Behaviour Change Methods (TBCM), which is extracted from the Intervention Mapping protocol (Approach #1). None of the five approaches recognise or mention either the Behaviour Change Wheel (BCW) or the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model). Two approaches, Approaches #1 and #4, recognise the PRECEDE-PROCEED Model; although while Approach #1 integrates it into its process, Approach #4 simply reviews and critiques it. Approach #2 is the only approach of the five that integrates Fogg's Behavioural Model (FBM) and the Persuasive Systems Design Model (PSDM).

Three of the five approaches (Approaches #3, #4 and #5) either discuss or draw from existing multi- and interdisciplinary approaches. Approach #5 makes active use of existing approaches by consciously integrating the first three steps of the Intervention Mapping process (Approach #1) with the first four components of the Behavioural Intervention Technology (BIT) Model (Approach #7). Approach #4, in comparison to Approach #5, does not actively integrate steps from existing approaches, but does review and note limitations of Approaches #1 and #3. Approach #3 does not explicitly refer to another existing approach in the initial article (Craig, et al., 2008); however, recent publications on the approach suggest the use and application of Approach #4 (6SQuID) within the first stage of Approach #3's four-stage process (Craig, et al., 2018). Unlike these three approaches, Approaches #1 and #2 do not draw on existing multi- and interdisciplinary approaches, although as previous discussed, Approach #2 is informed by a review of sixteen extant eHealth technology frameworks.

#### 6.4.1.4 Nature of Approaches and Process Steps and Activities

*Nature of the Approaches*

The nature and characteristics of an approach's process and its comprising steps (also referred to as stages, phases or components) influences how multi- and interdisciplinary teams

communicate and cooperate, as well as how they collaborate on and/or coordinate various tasks and activities in the mHealth behaviour change intervention app development process. The nature of all five of the multi- and interdisciplinary approaches in the Health Sciences Perspective category share four characteristics, namely that they are all systematic, cumulative, theory-based and evidence-based. Systematic describes a process as having methodical, organised and logical qualities. Cumulative denotes that the findings and outputs of prior steps (stages or phases) of a process inform successive steps, and that the work performed and artefacts created continue to gradually develop and grow over the duration of the enacted process. Theory-based essentially indicates that the steps within a process, or the process as a whole, are established on and supported by theory(ies), theoretical frameworks and/or models. Evidence-based conveys that the steps within a process, or the process as a whole, has been applied in practice and has demonstrated scientific proof (hence the word 'evidence') for validity, credibility and reliability. Four of the five approaches, with the exception of Approach #5, are iterative in nature. Iterative means that either certain steps within a process, or the process as a whole, can be repeated either one or more times. Three approaches, Approaches #1, #2, and #3, are described by the authors as non-linear, whereas Approach #4 is referred to as linear, and Approach #5 stipulates neither a non-linear nor linear nature. Linearity suggests that team members are required to follow the steps within an approach or process in an expected order or sequence. Whereas a non-linear approach or process indicates that team members need not necessarily follow the prescribed steps in an orderly or sequential manner. As far as other characteristics are concerned, Approach #2's phases and components are described by the authors as "intertwined", "dynamic", "flexible", "reflexive" and "reflective". Furthermore, they characterise the five phases of Approach #2 as being "interdependent", encompassing "continuous" connecting "cycles". Dissimilarly to Approach #2's continuous connecting cycles, Approach #3 is described by the authors as "not follow[ing] … a cyclical sequence" (Craig, et al., 2008, p.8). On another note, in comparison to the other four approaches, Approach #4 is the only approach that is explicitly referred to as "pragmatic" in nature. Pragmatic essentially denotes an approach and/or process that is concerned with practical, realistic, sensible and real-world application considerations, rather than theoretical considerations. Important to note is that a pragmatic approach can still be theory-based or theory-informed, but quintessentially aims to conduct a process in a practical and sensible way.

For the remainder of the critical theoretical comparative and thematic analysis, the terms systematic, cumulative, theory-based, evidence-based, iterative, linear, non-linear and

pragmatic may be used in the other subsections discussing the nature of multi- and interdisciplinary approaches (specifically Subsections 6.4.2.4, 6.4.3.4 and 6.4.4.4). The definitions for these terms will, however, not be repeated in every subsection.

### *Process Steps and Activities*

All five of the multi- and interdisciplinary approaches in the Health Sciences Perspective category provide a series of steps (also referred to as stages, phases or components) that constitute prescribed processes for guiding intervention designers and developers in developing technology-based (or non-technology-based) health interventions. The summary of the various process steps (stages, phases or components) for each health science approach is provided Table Appendix I.1. For each of the five processes, Table A in Appendix H provides detailed descriptions, sub-steps and activities for each step, as well as the methods, tools and artefacts used and/or produced at each step.

*Table Appendix I.1: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Health Sciences Perspective Category [Researcher's own construction]*

| Approach #1 | Approach #2 | Approach #3 | Approach #4 | Approach #5 |
|---|---|---|---|---|
| Step 1:<br>Logic Model of the Problem | Phase 1:<br>Contextual Inquiry | Stage 1:<br>Development | Step 1:<br>Define and understand the problem | **Phase 1:<br>Develop the Conceptual Framework using the<br>IM Approach** |
| Step 2:<br>Program Outcomes and Objectives – Logic Model of Change | Phase 2:<br>Value Specification | Stage 2:<br>Feasibility/Piloting | Step 2:<br>Identify factors for change | IM Approach:<br>Step 1<br>Step 2<br>Step 3 |
| Step 3:<br>Program Design | Phase 3:<br>Design | Stage 3:<br>Evaluation | Step 3:<br>Identify the change mechanism | **Phase 2:<br>Develop the Technological Framework using the<br>BIT Model** |
| Step 4:<br>Program Production | Phase 4:<br>Operationalisation | Stage 4:<br>Implementation | Step 4:<br>Identify delivery of the change mechanism | BIT Model:<br>Component 1<br>Component 2<br>Component 3<br>Component 4 |
| Step 5:<br>Program Implementation Plan | Phase 5:<br>Summative Evaluation | Stages 1 to 4 shared element:<br>Reporting | Step 5:<br>Test and refine on small scale | |
| Step 6:<br>Evaluation Plan | | | Step 6:<br>Evidence of effectiveness | |

### *Step 1*

Approaches #1, #2, #3 and #4 stipulate *Step 1* as incorporating the establishment of a multi- and interdisciplinary team, referred to either as a "stakeholder group", a "participatory group", or a "planning group". Establishing the multi- and interdisciplinary team can be referred to as *Activity 1.1* in the first part of *Step 1*. Formally constituting the multi- and interdisciplinary team allows for the various roles and responsibilities to be clearly defined, and different disciplinary perspectives to be acknowledged and respected. Approach #1 emphasises the importance in formalising principles of collaboration and cooperation, as well as the powers (and directions) of influence within the team. Approach #1 provides a list of recommended questions for guiding the selection and recruitment of suitable "stakeholders" or team members (Bartholomew Eldredge, et al., 2016, p.216). Questions relate to team members' different disciplinary knowledge, expertise and skills, the diversity of their heterogeneous perspectives and potential contributions, their authority(ies) and responsibilities, their influence of power, and their commitment(s) to the project and health problem at hand. Approaches #1 and #2 stress the active participation and full "buy-in" of all involved stakeholders or team members as imperative to a project's success. Moreover, Approach #1 discusses the significance of team management and team facilitation processes, and underscores the role of communication, task functions and team building functions in facilitating and maintaining group cohesiveness and productivity. For example, team facilitation processes for communication can include explicit and clear frames of reference, and honest descriptions of feelings and behaviours. For task functions, examples include initiating, information seeking, elaborating, coordinating, partialising, summarising, and synthesising. For team building and maintenance, examples include gatekeeping, encouraging, harmonising, consensus seeking, standard setting, processing, and giving constructive feedback. Furthermore, Approach #1 details the value in formalising multi- and interdisciplinary team protocols for decision-making and consensus building, which can be used to guide team communication, collaboration, coordination and cooperation at each stage of the intervention development process. Similar to some of the points made by Approach #1, Phase 1 (Contextual Inquiry) in Approach #2 involves identifying relevant stakeholders (team members), specifying their various roles and responsibilities, and performing a stakeholder analysis. Phase 2 (Value Specification) in Approach #2 also includes determining what values are deemed important to participating stakeholders (team members), which may reveal similarities, differences and possibly even conflicts in the values held by different contributing members. On a final note with regard to the dynamics and management

of a multi- and interdisciplinary team, Approach #1 discusses the importance of culture, and that an awareness and understanding of the cultural diversity between participating team members is necessary, as well as the culture of the team together as an interconnected whole (Approach #1). In comparison to Approaches #1 and #2, Approaches #3 and #4 provide considerably less detail on the formalities, protocols, dynamics, facilitation and management of multi- and interdisciplinary teams. In contrast, Approach #5 neither discusses multi- and interdisciplinary team formation nor any other team related considerations.

In addition to multi- and interdisciplinary team formation, a critical comparative review of the second part of *Step 1* reveals all five of the health sciences approaches as aiming to perform a needs assessment (also referred to as formative research). Conducting a needs assessment can refer to *Activity 1.2 in Step 1*. This essentially entails analysing and understanding the health problem (in relation to quality of life), the intervention context and the target population group involved. Gaining an understanding of a given health problem requires investigation into the correlated and causal at-risk factors and the determinants associated with the particular health problem, which can be used to inform causal pathway linkages. Approach #1 and #5 suggest creating a graphical illustration of these pathways by developing a "Logic Model of the Problem" (diagram), guided by the PRECEDE segment of the PRECEDE-PROCEED Model. The Logic Model of the Problem is developed from right to left, starting with descriptions of quality of life (on the far right), followed by the health problem(s), then moving to (behavioural, social and environmental) contributing risk factors, and lastly to personal determinants (on the far left). All five approaches suggest developing the Logic Model of the Problem by reviewing applicable evidence-based theory, and reliable and credible findings from relevant literature and empirical studies. Example depictions of the Logic Model of the Problem can be referred to in Approach #1 (Bartholomew Eldredge, et al., 2016, p.227; p.259). If needs be, Approach #1 suggests first defining a "statement of need", which can offer a concise statement of the health problem (yet must not offer any proposed solution). This statement is most beneficial if specified prior to developing the Logic Model of the Problem, and provides a means of framing the intervention development team's specific problem focus. Approach #1 describes a needs assessment as essentially detailing the discrepancy between what is (the current state) and what should be (the desired state). In addition, Phase 1 (Contextual Inquiry) in Approach #2 suggests investigating social and technological problems and issues related to the health problem situation. Step 1 in Approach #4 also recommends understanding lifestyle consequences associated with the health problem, and differentiates between proximal and distal influencing

factors. Further explication of the needs assessment requires an investigation into and an understanding of the target population group, and the likely contexts they find themselves in; both in relation to the specified health problem. All five of the multi- and interdisciplinary approaches in the Health Sciences Perspective category explain how this understanding facilitates drawing links between what needs to be targeted, what needs to change, and for whom.

### *Step 2*

Based on the needs assessment and the Logic Model of the Problem (diagram), Approach #1 and #5 specify *Step 2* as developing the Logic Model of Change (diagram). A cross-comparison between the five health sciences approaches reveals Step 2 in Approaches #1 and #5 to be equivalent to Steps 2 and 3 in Approach #4. Whereas Step 2 in Approaches #1 and #5 is encapsulated in Stage 1 in Approach #3, and Step 2 corresponds to aspects of Phase 2 in Approach #2. The Logic Model of Change essentially specifies the goals, outcomes and objectives of a health promotion programme (Approach #1) or an mHealth physical activity behaviour change intervention app (Approach #5). *Activities 2.1, 2.2* and *2.3* comprised in *Step 2* include: stating the health behavioural outcomes; creating a value specification; specifying performance objectives for the behavioural outcomes; and selecting the most promising (evidence-based and importance-ranked) behavioural change determinants for the performance objectives, which in turn influence the behavioural outcomes. For *Activity 2.1*, health behavioural outcomes can be framed as either health-promoting behaviours (such as increasing physical activity) or risk-reducing behaviours (such as reducing physical inactivity, or reducing sedentary behaviour). Approach #1 explains that the behavioural outcome of a particular health intervention programme ought to be clearly stated; for example, "engage in moderate to vigorous physical activity at least 150 minutes a week", or "perform aerobic exercise for 30 minutes per day". Health behavioural outcomes are synonymously referred to as mHealth app intervention goals by Approach #5. Approach #2 also aims to define an intervention's goals and sub-goals, however, not in relation to health or mHealth intervention outcomes, but in terms of eHealth technology goals. Approach #2 is the only approach of the four that suggests creating a value specification (in Phase 2), which encompasses the following: an outline of the value added by the eHealth technology; a specification of the goals that the eHealth technology should reach according to stakeholders; a description for how the eHealth goals intend to be met; and a stipulation of the demands from the eHealth technology implementation context

(van Gemert-Pijnen, et al., 2019). A value specification also elaborates on the processes for determining, prioritising and categorising users' needs and values, and translating them into specific intervention requirements, and further aims to create and include a value map and a business model. Approach #2's value specification and Approach #5's mHealth app intervention goals contribute to enriching the outcomes for the health behavioural change intervention.

In referring back to the health behavioural outcomes, an intervention may have one or more behavioural outcomes, depending on the targeted behavioural complexity (for example, targeting physical activity alone, or simultaneously targeting physical activity, healthy eating, sleep and stress reduction together). Each behavioural outcome is then broken down into performance objectives. According to Approach #1, performance objectives are observable and actionable subsets of behaviour, that together, lead to a behavioural outcome. In *Activity 2.2*, performance objectives help intervention designers and developers clarify what exactly needs to or can be performed in order to enable the transition towards the health behavioural outcome. Simply put, health behavioural outcomes are broad conceptualisations, whereas performance objectives are specific and practical, in terms of what a given target population group is both able and willing to do (Approach #1). In the context of physical activity, performance objectives can, for example, include: "create awareness on the benefits of maintaining physical activity"; "create social support networks to maintain pattern of physical activity"; "create an action plan with realistic goals to achieve physical activity pattern"; and "monitor physical activity pattern". Notably, the performance objectives should be detailed in a logical sequence, as portrayed in the physical activity example. Following the specification of performance objectives, intervention designers and developers select the behavioural change determinants that are evidenced to be the most promising, modifiable and malleable, and are likely to have the greatest influence and impact for change. In *Activity 2.3*, Approaches #1 and #5 recommend selecting the 'most promising' determinants that are evidence-based, and ranking them by importance and changeability (based on the extent of available evidence for influence). Approaches #1 and #5 also discuss the value of identifying "personal determinants", which are correlated or causal factors that can change the way an individual perceives, thinks about, feels about, and behaves with regard to a particular health behaviour. These determinants are orientated towards targeting an individual on an intrapersonal level, and operate in terms of an individual's psychological, cognitive, emotional, attitudinal, biological, physiological and behavioural processes and capabilities. Some of these determinants roll over into primary

interpersonal [inter(primary)] determinants. Many determinants are often based on or informed by evidence-based and validated theories or theoretical models. In the context of physical activity, common examples of determinants include self-efficacy, autonomy, outcome expectations, attitudes, knowledge, perceived behavioural control, perceived competence, perceived level of fitness, social norms, social support, social influence and modelling (Biddle and Mutrie, 2008; Rhodes, McEwan and Rebar, 2019). Drawing from theory to identify and select evidence-based personal determinants is referred to in Approach #1 as utilising "core processes".

After the third activity in *Step 2* – that is, having selected (evidence-based and importance-ranked) behavioural change determinants for the performance objectives – intervention designers and developers perform *Activities 2.4* and *2.5*: construct change objective matrices; and develop a Logic Model of Change. This totals five activities in *Step 2*. In terms of *Activity 2.4*, according to Approaches #1, #4 and #5, Matrices of Change are constructed by crossing and linking performance objectives with behavioural change determinants, and writing change objectives for each cross-link. Change objectives describe what specifically needs to change on each particular determinant (that is, the actionable changes) in order to meet or obtain performance objectives. Matrices of Change are set out in a tabularised format: listed performance objectives (far left column); determinants (horizontal top row); change objectives (cross-linked cells). General example tables of the Matrices of Change can be referred to in Approach #1 (Bartholomew Eldredge, et al., 2016, p.315-316; p.319). In the context of physical activity and mHealth smartphone apps, some examples of change objectives identified by Approach #5 include: "feel positive about being more physically active", "feel positively about self-monitoring", "identify which activities are personally enjoyed", "ask for support when needed", "be aware of the physical activity guideline recommendations", and "make activity plans suit personal preferences". Subsequent to constructing matrices of change in *Activity 2.4*, intervention designers and developers create a Logic Model of Change (diagram) in *Activity 2.5*. In comparison to the Logic Model of the Problem, which illustrates the causal pathways of a health problem, the Logic Model of Change depicts the intended pathways of a health intervention's (or programme's) effects. The Logic Model of Change does, however, build on and extend from the Logic Model of the Problem. In *Activity 2.5*, the Logic Model of Change is developed from left to right, in comparison to the Logic Model of the Problem which is developed right to left. The Logic Model of Change starts with change objectives (on the far left) which includes the selected determinants x performance objectives, then moves rightwards

to health behavioural outcomes, followed by the health problem(s), and lastly to the quality of life descriptions (on the far right). A general example depiction of the Logic Model of Change is provided in Approach #1 (Bartholomew Eldredge, et al., 2016, p.320). Instead of only referring to the Logic Model of Change, Approach #4 also refers to Program Theory, which is also utilised to diagrammatically illustrate an intervention's intended change effects.

### *Step 3*

Following *Step 2* is *Step 3*. Approach #1 specifies Step 3 as designing the programme (or health behavioural change intervention), and Approach #5 stipulates Step 3 as selecting theory-informed methods and practical applications. In *Step 3*, based on the Logic Model of Change developed in Step 2, intervention designers and developers begin to conceptualise, ideate and design the health programme (or health behavioural change intervention). In comparing Step 3 in Approach #4 to Step 3 in Approaches #1 and #5, the activities in Approach #4's Step 3 are amalgamated with the Logic Model of Change, which is the same model that Approaches #1 and #5 position under Step 2 (and not Step 3). More differences are identified in that the activities encompassed in Step 3 of Approaches #1 and #5 remain wound up in Stage 1 of Approach #3. This is similar to how Step 1 and Step 2 of Approaches #1 and #5 are wound up in Stage 1 of Approach #3 (as discussed above). Given the researcher's orientation of focus in this critical theoretical analysis, attention is turned towards the commonalities shared between Approaches #1 and #5 for *Step 3*, which can be divided into *Activities 3.1*, *3.2* and *3.3*: generate programme (or intervention) themes, components, scope and sequence; choose (match and select) theory-informed and evidence-based change methods; and translate these methods into practical strategy applications. *Activity 3.1* involves creating the general design plan for the intervention. Approach #1 suggests utilising creative idea generation techniques such as brainstorming and lateral thinking to generate ideas for the intervention's design, and that all of the multi- and interdisciplinary team members should be involved to ensure shared understanding of the (work-in-progress) intervention design solution space. Detailing the intervention's design also includes outlining the themes, subthemes, components (units or modules), scope and sequence. Additionally, the intervention's design should align with the findings from the needs assessment; for example, it should be in accordance with the target population group's needs and preferences, and their particular contexts-of-use. Approach #1 describes an intervention's theme and subthemes as pertaining to the general idea(s) or construct(s) for the design, which may ultimately be conveyed to intervention users via a form

of “brand”, such as “we walk together” for a physical activity behaviour change app. Components may incorporate various combinations of change objectives, performance objectives, change methods, or practical applications (of which the latter two would be informed by *Activities 3.2* and *3.3*). Scope refers to the breadth and depth of the intervention’s design, and sequence details how components are set to unfold (or be delivered) over time (through interactive use).

*Activity 3.2* in *Step 3* involves identifying, matching and selecting theory-informed and evidence-based change methods based on the selected ‘most promising’ determinants. Approaches #1 and #5 describe a theory-based change method as a technique intended to change a particular behavioural determinant of an individual. Approaches #3 and #4 discuss change mechanisms (or mechanisms of change) as synonymous with theory-based change methods. As the authors of the Behaviour Change Methods Taxonomy for the Intervention Mapping protocol (Approach #1), Kok, et al. (2016) describe theory-based methods as equivalent to behavioural change methods. They also describe them as techniques or processes that have shown to be effective (that is, evidence-based) in changing one or more determinants of health behaviour of the particular at-risk target group (Kok, et al., 2016). To explicate more, ‘theory-based’ denotes that the methods or techniques have origins in behavioural science and psychosocial science theories, and that often evidence for a method or technique is provided in several theories (Kok, et al., 2016). These roots of theoretical origin further justify and verify the classification of these multi- and interdisciplinary approaches in the Health Sciences Perspective category. Essentially, the theory explains how the change mechanism (or mechanism of action) works, thus demonstrating its explanatory and (correlational or causational) predictive power (Kok, et al., 2016). In essence, Approaches #1, #3, #4 and #5 emphasise the importance of theory-informed (or theory-based) and evidence-based behavioural change methods (change mechanisms) as necessary and crucial to the design and development of effective health behaviour change interventions. On another important note, theory-based methods (or change mechanisms) are interchangeably referred to as behaviour change techniques in Approaches #3, #4 and #5, as well as by Kok, et al. (2016). Behaviour change techniques (BCTs) can be defined as the specific, active ingredients and smallest components constituting a health behavioural intervention. Approach #5 mainly utilises two coding (and reporting) BCT taxonomies, namely the CALO-RE Taxonomy (Michie, et al., 2011) and the BCTT v1 93-item hierarchically clustered taxonomy (Michie, et al., 2013). Approach #1, in comparison, is usually associated with using a development taxonomy, namely

the Taxonomy of Behaviour Change Methods (TBCM) (Kok, et al., 2016). Approach #5 does, however, recognise the value of this latter development taxonomy, particularly given it provides explicit parameters (or conditions) that need to be met for each change method (change mechanism or BCT) to be effective. For mHealth physical activity apps in particular, examples of commonly used evidence-based BCTs include: goal setting; self-monitoring; action planning; feedback on behaviour; social support; graded tasks; problem-solving; habit formation; prompts/cues; self-talk; and rewards (Approach #5). Parameters for the goal setting BCT, for instance, include: commitment to the goal; the goal should be challenging but achievable within a given individual's skill level (Approach #5; Kok, et al., 2016). Parameters for the graded tasks BCT, for example, include: the target behaviour can be reduced to easier, but increasingly challenging, sub-behaviours (Approach #5; Kok, et al., 2016). Parameters for the habit formation BCT include: the existence of positive intention; and a sense of awareness (Approach #5; Kok, et al., 2016). Furthermore, when selecting BCTs, it is critical that intervention designers and developers choose specific techniques that have demonstrated real-world effectiveness for the particular target population group and the defined contexts-of-use (Approaches #1 and #5). Importantly, literature repeatedly argues that "a crucial lesson from the accumulated evidence in many different areas is that what is effective for a given behaviour, delivered in a particular way, in a given target group and a given context may not be effective for other behaviours, target groups, etc." (Michie, et al., 2013, p.14; Kok, et al., 2016). Approaches #4 and #5 also caution to "not assume that methods or BCTs will be uniformly effective across conditions" (Direito, et al., 2018, p.333), and caution to not be overly or "wildly optimistic" of change mechanisms or BCTs that lack sufficient empirical evidence (Wight, et al., 2015, p.4).

Following the selection of BCTs (also referred to as theory-based methods and change mechanisms) in *Activity 3.2*, *Activity 3.3* in *Step 3* aims to translate, operationalise and organise these techniques (methods or mechanisms) into practical strategy applications. A practical application refers to the way in which a specific strategy is translated from a theory-based method into a practical element in a particular intervention, and how the parameters of effectiveness will be satisfied, whilst meeting the characteristics of the intended target population and the defined contexts-of-use. Approach #1 simply describes a practical application as an idea about how to deliver a particular method. Practical strategy applications can be informed by reviewing literature, findings from empirical studies, and by reviewing real-world existing similar successful health behavioural interventions (for example, reviewing

existing physical activity apps on the consumer app market). Furthermore, linkages between behavioural change determinants, BCTs (theory-based methods), parameters of effectiveness, and operationalised practical applications can be summarised in tabularised format, presented as tables for easier review and referral. Approach #5 provides a table illustrating these linkages for mHealth physical activity apps in particular. Some examples of translations from BCTs into practical applications by Approach #5 include: providing information on local groups that offer support physical activity, or suggesting walking with a friend (for BCT social support); agreeing on a specific time spent (goal) for daily physical activity with the individual user (for BCT goal setting); providing personal feedback on activity, providing positive feedback on approximation to goals, and informing the individual how much time they spent active each day (for BCT feedback on behaviour); and congratulating the individual for each and every day they try reach their goals (for BCT rewards). All in all, the completion of *Activities 3.1*, *3.2* and *3.3* in *Step 3* marks the transition to *Step 4*.

### *Step 4*

The particularities of the activities pertaining to *Step 4* exhibit a number of differences across the five multi- and interdisciplinary approaches in the Health Sciences Perspective category. On the one hand, Approach #1 – the Intervention Mapping (IM) protocol – specifies Step 4 as programme production, which results in the design and production of the intervention materials. On the other hand, while Approach #5 employs Steps 1, 2 and 3 of the IM protocol (Approach #1) in Phase 1 to guide the development of the conceptual framework, in Phase 2, from Step 4 onwards, it adopts the BIT Model and the BIT-Tech Model (Approach #7) to translate the conceptual framework into a technological framework. The authors of Approach #5 explain that it is at Step 4 – the production of the intervention components – where "the IM was integrated with BIT in order to translate the BCTs into the 'user-facing' app features" (Direito, et al., 2018, p.333). This conceptual-technological translational view is similar to Step 4 in Approach #4, which stipulates identifying how to deliver the change mechanisms (that were selected in Step 3). In comparison to Approaches #1, #4 and #5, Step 4 corresponds to Phase 3 in Approach #2, which specifies the main activity as "Design". In Approach #2, design encompasses the employment of persuasive design principles and techniques to translate users' needs into technical features for eHealth technologies. In contrast to the other four approaches, where steps and phases have demonstrated progression through the development process, Approach #3 continues to nest Step 4 within Stage 1; similar to how it nests Steps 1, 2 and 3

within Stage 1 (as discussed above). Nevertheless, overall, it is during *Step 4* of the intervention design process that Approaches #1, #2, #4 and #5 pay significant attention to the mode or platform through which a particular health behavioural intervention intends to be delivered to individuals (end users). Approach #5, for instance, focuses on using mobile smartphone apps as the chosen platform for delivering a particular physical activity behaviour change intervention. It is at this stage that Approaches #4 and #5 stress the importance of understanding the characteristics, strengths and limitations of the selected delivery platform. Approach #5, for example, argues for several strengths that can be leveraged with the smartphone app platform, including: the dynamic and adaptable nature that enables context-sensitive just-in-time intervention component delivery; opportunities for personalised content and tailored features (intervention components); as well as smartphones' sensing capabilities that allow for the tracking, measuring and recording of individuals' movements (such as step-counting). Limitations of smartphone apps noted by Approach #5 include: difficulties in tailoring an intervention to suit differences between various individuals, and simultaneously tailoring an intervention to fit differences for a specific individual over time (since their physical activity needs continue to change as they adhere to the intervention over time).

In reviewing Approach #1, the activities in *Step 4* are generally concerned with integrating the theory-based methods and practical applications (from *Step 3*) into an organised health programme. In Approach #1, Step 4 involves four activities, namely: refining the programme structure and organisation; preparing plans for the programme's materials; drafting the objective and contextual messages, materials and protocols; and pre-testing, refining and producing the materials. These activities essentially focus on producing messages and materials that bring the program design (from *Step 3*) to life, appropriately translating and operationalising methods to practical applications within the given parameters of effectiveness, and focusing on ensuring that messages and practical applications are suited to the target population and use contexts. In comparison to Approach #1 which is not orientated solely to technology-based intervention platform delivery, Step 4 in Approach #5 specifically aims to translate and operationalise the intervention components (BCTs, theory-based methods, practical strategy applications) into technological features for a specific mHealth physical activity behaviour change intervention app. Therefore, the first activity in Step 4 in Approach #5 involves specifying and distinguishing between the clinical (health intervention) aims and usage (technological) aims of a given health behavioural change intervention. Following this, activities in Approach #5's Step 4 include: establishing the workflow [the set of rules and

algorithms that determine when and under which conditions the BIT elements (intervention components) are displayed and delivered to users over time]; developing the (user) profiler; creating the intervention planner [which chooses the relevant BIT elements and respective characteristics]; constructing the intervention repository [the storage database for the BIT elements]; and developing the app's user interfaces [which delivers the visual, audible and haptic BIT elements to the individual app user]. In carrying out these activities in Step 4, Approach #5 recommends tabularising the translations and operationalisations of BCTs into BIT elements by creating a table that allocates cross-links for determinants, BCTs, operationalised practical applications, BIT elements, and workflow. An example of these tables is provided in the main publication article of Approach #5 (Direito, et al., 2018, p.341) as well as in the article's supplementary material (Direito, et al., 2018, Supplementary Material 1, link provided on p.345). In Step 4, Approach #4 also cautions that careful consideration be taken when translating and operationalising practical strategy applications into real-life materialised messages and elements, particularly given the specific preferences and requirements of the target population group and the defined contexts-of-use. For example, caution can be practiced by clarifying the assumptions made, being aware of and minimising any potential risks, and taking precautions in avoiding or minimising any possible unintended adverse consequences that can result from various intervention messages and elements. On a final note for *Step 4*, Approach #1 recommends tracking and recording the intervention's design and creative translation process in a compiled design document, which all of the multi- and interdisciplinary team members can access and refer to when necessary.

### *Step 5*

In moving from *Step 4* to *Step 5* – subsequent to the production, translation, operationalisation and organisation of intervention components (messages, materials and protocols) or BIT elements (and workflow) – Approaches #2, #3 and #4 discuss formative evaluations. In *Step 5*, formative evaluations essentially involve organising and running feasibility and pilot testing studies, which can be, and often are, iterative in nature. Approach #2 discusses feasibility and pilot testing during Phase 3 (Design), where relevant and skilled multi- and interdisciplinary team members are tasked with facilitating and performing a series of usability tests. The main purpose of usability testing is to iteratively improve the design of an intervention's elements and features over time by running a series of several design-test-refine cycles that results in the production of various low- and high-fidelity prototypes. Approach #2 suggests these tests be

carried out with prospective users (as representatives of the target population groups), specialist experts (such as user experience designers, usability designers, app designers), and/or with other interested and relevant stakeholders. Approach #2 also places emphasis on creating a highly rapid cyclical, iterative, dynamic and multi-participatory collaborative design-test-refine atmosphere. In comparison to Approach #2, Approach #3 discusses feasibility and pilot testing in Stage 2. The activities in Stage 2 nevertheless fall here under the discussion on *Step 5*, where Approach #3 mentions paying attention to carefully selecting small (yet representative) sample sizes of suitable participants (target population users), and being cautious about issues pertaining to ethics, recruitment, acceptability, compliance, retention and delivery. Similar to *Step 5* discussed in this review, Approach #4's Step 5 aims to test and refine a health behavioural change intervention on a small scale. When conducting the formative evaluations and usability tests, Approach #4 also suggests testing for: user acceptability; optimum intervention content and technique inclusion; intervention structure and duration; messages, materials and design interfaces of the delivery platform; and ways to design for maximum reach potential. Moreover, Approach #4 recommends aiming to achieve a "good enough" intervention design, particularly given any constraints and limitations of the selected mode or platform of intervention delivery. Lastly, Approaches #3 and #4 mention employing incremental and adaptive techniques, which aim to pilot test the feasibility of a particular subset of all possible values (components or features) or test the effects of different combinations of values (components or features), rather than test the complete set of variables, of an intervention. Approach #3, for instance, makes reference to the Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018). In the first "preparation phase" (also referred to as the screening phase) of MOST, feasibility testing can be conducted on each candidate intervention component to determine whether it is acceptable and understood by users, whether it is safe, unduly demanding on the intervention team and the participants, and whether it remains within resource, cost and time bounds (Collins, 2018, p.54). Notably, the second and third phases of MOST, namely the "optimisation" and "evaluation" phases, are not applicable to pilot and feasibility testing in *Step 5* (Collins, 2018, p.27).

### *Step 6*

After *Step 5* is *Step 6*. *Step 6* can be drawn from Approaches #1, #2 and #3, which correspond with Step 5 (Programme Implementation Plan), Phase 4 (Operationalisation) and Stage 4

(Implementation), respectively. However, with regard to Approaches #1 and #2, although they both refer to an implementation step, their interpretation of the term is distinctly different. On the one hand, Approach #1 describes a programme implementation plan as guiding the multi- and interdisciplinary team in terms of intervention adoption, real-world implementation, and maintenance, regarding both the initial use of an intervention and the later scaling-up of an intervention. According to Approach #1, an implementation plan should clearly outline a programme's outcome and performance objectives, provide change objective matrices for a programme's use, and guide the overall implementation process. Moreover, an implementation plan should incorporate materials for awareness promotion, support training for implementers, and an implementation manual (for quick and easy referral). On the other hand, in comparison to Approach #1 where the implementation plan (Step 5) is developed prior to summative evaluation (Step 6), Approach #3 specifies implementation (Stage 4) after summative evaluation (Stage 3). In Approach #3, implementation refers to the dissemination, surveillance, monitoring and long-term follow-up of a particular health intervention. Although, similarly to Approach #1, implementation in Approach #3 also involves the development of an implementation plan and training and support manuals. A critical review and comparison of the two different sequences – namely implementation before (Approach #1) or after (Approach #3) summative evaluation – surmises that the former option is most likely more practical, rational and effective. The main reason for this critically-informed thought trial judgement is that formal plans for an intervention's implementation, training and support should ideally be developed prior to real-world roll-out. Developing plans for an intervention's delivery, training and support subsequent to performing summative evaluation studies (like in Approach #3) seems counter-intuitive, especially considering that implementation needs to take place (even if on a small scale) before an intervention can be evaluated. On an additional note, the activities in Phase 4 (Operationalisation) in Approach #2 corresponds to the activities mentioned in the two implementation stages discussed in Approaches #1 and #3. In like manner, Approach #2 also discusses developing an implementation plan and a practical roll-out strategy that implementers can refer to in guiding the concrete real-world implementation of an intervention. However, unlike Approaches #1 and #3, Approach #2 also includes implementation activities concerning the development of marketing plans, organisational work procedure plans, and finalised plans for business model execution. In contrast to Approaches #1, #2 and #3, Approaches #4 and #5 do not include an implementation step (stage or phase).

### *Step 7*

Lastly, as a final step in the development process, *Step 7* focuses on the summative evaluation of a health programme or a health behavioural change intervention. Four of the five multi- and interdisciplinary approaches in the Health Sciences Perspective category, namely Approaches #1, #2, #3 and #4 discuss summative evaluation, whereas Approach #5 fails to mention and discuss summative evaluation altogether. The four approaches share an initial activity that aims to determine specific indicators and measures applicable for evaluating the effectiveness of a health intervention, particularly given the initially defined behavioural outcomes and intervention goals and sub-goals. Approach #2 additionally aims to determine measures that assess the adoption, usage, adherence and impact effectiveness of the eHealth technology, and not only the health intervention. This distinction differentiates between evaluating the platform of intervention delivery and evaluating the intervention itself. Another important shared activity is identifying and selecting suitable evaluation methods to assess the effectiveness of the intervention. Randomised controlled trials (RCTs) on both smaller and larger scales are the most referenced evaluation method for summative evaluation studies. The main reason for this is their distinction as the gold standard for health and medical testing. Approach #3 also mentions distinguishing between primary and secondary clinical trial outcome measures. Approaches #3 and #4 further note an awareness for any potential adverse evaluation trial study consequences or unintended effects. In light of these concerns, Approach #3 discusses the importance of adhering to strict ethical protocols and taking active action to counter any possible biases. In comparison to the other approaches, Approach #1 is the only approach that explicitly discusses the development of a summative evaluation plan, which outlines all of the summative evaluation protocols and details. Furthermore, Approaches #1 and #3 discuss clinically evaluating the change processes within a given intervention, to test and identify which mechanisms have a significant (or ineffective or even adverse) impact in a particular context setting. Overall, summative evaluation is a necessary and important step in the health intervention development process because it essentially assesses and determine whether an intervention is achieving its pre-determined intentions, and fundamentally helping promote and improve peoples' health and wellbeing. Moreover, Approach #3's brief reference to the Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018) allows the intervention team to perform experiments that evaluate and determine the effectiveness of specific intervention components, or specific set

combinations of intervention components, BIT elements, messages and design features of a mHealth physical activity behaviour change intervention app.

On a second last note, Approach #3 is the only approach of the five multi- and interdisciplinary approaches in the Health Sciences Perspective category that discusses the importance of continuous quality reporting at each step of the intervention development process. On a final note, Approach #2 is the only approach that emphasises ongoing project and stakeholder management throughout the intervention development process. Some of these management activities include focusing on keeping a project on track, detecting problems as early as possible, solving issues and addressing problems as quickly as possible, and ensuring a continuous productive relationship between all participating and collaborating stakeholders (team members) over the lifespan of a given health intervention project.

### *Summary of Process Steps and Activities: Health Sciences Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.1.4, Figure Appendix I.1 provides a summarised high-level graphical illustration of the key themes and subthemes identified in the process steps (and activities) of the five multi- and interdisciplinary approaches in the Health Sciences Perspective category.

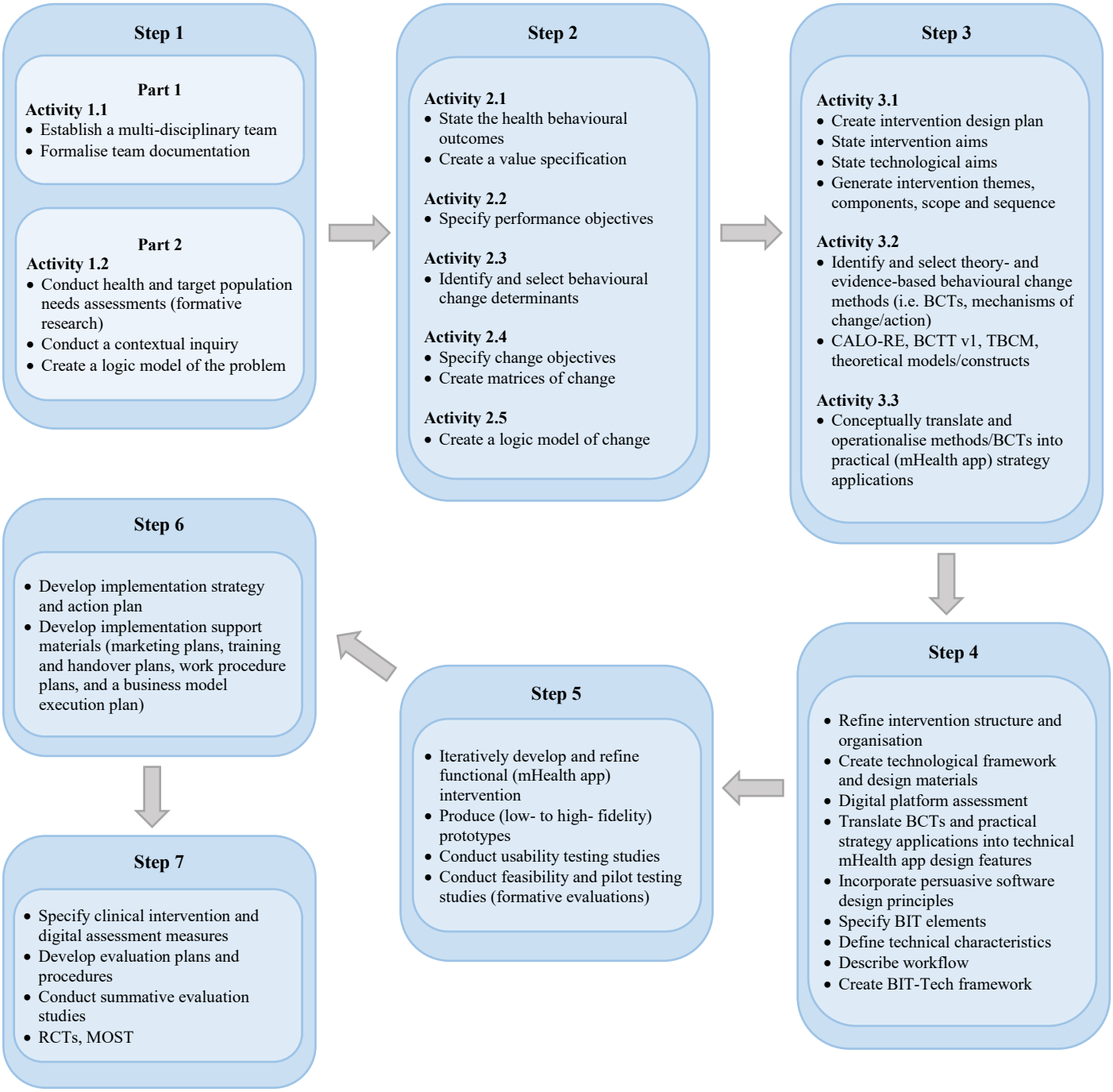



*Figure Appendix I.1: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Health Sciences Perspective Category [Researcher's own construction]*

#### 6.4.1.5 Design Artefacts, Boundary Objects and Supporting Methods

*Step 1*

For the first part of *Step 1* establishing and formalising a multi- and interdisciplinary team requires that particular supporting materials be developed. Approach #1 provides a list of recommended questions that can be used to guide the selection and recruitment of suitable team members, relevant to the contextual particulars of a given health behavioural intervention

project (Bartholomew Eldredge, et al., 2016, p.216). Approaches #1 and #2 emphasise the creation of team documentation, which should clearly outline each team member's: disciplinary background(s); areas of knowledge, expertise, skills and experience; potential/intended contributions; values; role(s); authority(ies); responsibilities; influence of power (in terms of activities and decision-making); and involvement and activity commitments. Team management and team facilitation processes and documentation are vital for supporting, guiding and managing the team's cross-disciplinary collaborative, cooperative and coordinated efforts throughout the health behavioural change intervention development process. Team documentation should cover: roles and principles of communication; task functions; team building and maintenance functions; team facilitation processes and guidelines; team cohesiveness guidelines; decision-making and consensus building procedures; conflict-resolution procedures; and principles of team culture (Bartholomew Eldredge, et al., 2016, p.217-224). In addition, intervention project documentation should involve input from all of the heterogeneous team members and should have full buy-in and contract sign-off before the intervention development process commences.

For the second part of *Step 1* the team employs and uses a variety of artefacts, objects and research methods to perform a contextual inquiry into and needs assessment of the health problem space (also referred to as formative research). All five of the health sciences multi- and interdisciplinary approaches emphasise the value in reviewing literature and findings from published empirical studies, all of which should be applicable to the specific problem of focus. Approaches #1, #2 and #3 additionally discuss the importance of conducting primary research using qualitative and quantitative methods, including: interviews; surveys; questionnaires; workshops; field observations; personas; scenarios; focus groups; diary studies; data logs; secondary data analyses; think aloud techniques; expert meetings and expert reviews; and numerical and statistical analyses. Furthermore, Approaches #1, #3, #4 and #5 utilise logic modelling techniques (such as the PRECEED Model) to graphically illustrate the health problem. The Logic Model of the Problem (diagram) can act as a boundary object to facilitate a shared and mutual understanding of the problem space between team members, particularly in terms of explicitly clarifying what causal pathways are evidenced to link the health problem with associated at-risk (proximal and distal) factors and individual and interpersonal determinants. Approach #5 also refers to and uses the World Health Organisation's *Global Recommendations on Physical Activity for Health* (WHO, 2010) to better understand the evidence-based needs and determinants of physical activity for individuals worldwide.

Moreover, in addition to understanding the health problem space, all five health sciences multi- and interdisciplinary approaches discuss conducting a needs assessment with the target population group.

The initial outputs from part one of *Step 1* include all of the formalised multi- and interdisciplinary team protocols, guidelines, documentation and contracts, along with a clear list of the participating team members and a stakeholder analysis summary. The main outputs from part two in *Step 1* include: a health problem statement (including a concise definition and description of the current situation); a needs assessment of the health problem (which can include a table on the at-risk factors and modifiable determinants in relation to the targeted health behaviour); a Logic Model of the Problem (diagram); a target population group statement (including a clear description of the characteristics, demographics and contexts of the target audience); a needs assessment of the target population group (relating to and including an understanding of the target health behaviour); and documentation reporting on primary studies conducted (including study designs, ethical approval, data results, findings and analyses).

### *Step 2*

All of the five health sciences approaches use outputs from *Step 1* together with further reviews of literature and extracted findings from published empirical studies to inform activities and artefacts in *Step 2*. In addition, *Step 2* employs a variety of other artefacts, objects and research methods with the intention to specify the goals, sub-goals and objectives of the health behavioural change intervention solution space. Approach #2, for instance, uses a business model canvas and value map as templates to detail the business perspective and the value specification of the digital health intervention project. Approach #5 draws on constructs from theoretical models including the integrated behaviour change model (IBCM), self-determination theory (SDT) and theory of planned behaviour (TPB) to specify performance objectives for the health behaviour change intervention. Approaches #1, #3, #4 and #5 also draw from evidence-based theories and core processes to inform the intervention's solution goals and objectives. The team can further reference Approach #1's guidelines when creating change objective and performance objective matrices (tables). Similarly to *Step 1*, Approaches #1, #3, #4 and #5 utilise logic modelling techniques to graphically illustrate the mechanisms involved in changing the target health behaviour for the defined target population group. The Logic Model of Change (diagram) can act as a boundary object for collaborating team members

to facilitate a shared and mutual understanding of the change mechanisms, particularly in terms of explicitly clarifying the causal pathways evidenced to link change objectives, performance objectives, determinants and health behavioural outcomes. Approaches #1 and #5 recommend selecting determinants that have shown to demonstrate potential in effecting changes to individuals' health behaviour(s). Also similar to *Step 1,* Approach #5 makes use of World Health Organisation's *Global Recommendations on Physical Activity for Health* (WHO, 2010) to guide the goals and objectives for the health behavioural change intervention.

The main outputs for *Step 2* that are relevant to the health behavioural change intervention include: a statement (or list) of the health behavioural change interventions goals and sub-goals; a health behavioural outcome(s) statement; a list of the performance objectives; a list of the selected evidence-based determinants; matrices (tables) of change objectives (linking performance objectives and determinants); a Logic Model of Change (diagram); and documentation reporting on primary studies conducted (including study designs, ethical approval, data results, findings and analyses). The main outputs for *Step 2* applicable to the technological and digital perspective (Approaches #2 and #5) include: a value specification; a technological value map; a statement and description of the technological and digital aims and scope; and a list of the technological and digital (prioritised) requirements and specifications. Approach #2 also discusses outputs from a business perspective, specifically a business model (canvas). Another key output for *Step 2* concerns the team's business model, which provides a rationale for how the team aims to foster ownership and business cases, as well as create, deliver and capture specified values, goals and objectives, and further outlines the cost-benefit structure of the intervention project.

### *Step 3*

The outputs from *Step 2* together with additional artefacts, objects and research methods are employed and utilised to carry out activities and produce artefacts during *Step 3*; all of which essentially aims to conceptualise, ideate and plan the health behavioural change intervention. Creative idea generation techniques such as brainstorming and lateral thinking can be employed initially by the team to generate ideas for the intervention's conceptual solution, themes and sub-themes. Following this, a key part of *Step 3* is concerned with reviewing, identifying and selecting suitable intervention components based on the most promising determinants (identified in *Step 2*). This process first requires the team to choose theory- and evidence-based change methods. Across the five health sciences approaches, theory-based

change methods are referred to synonymously as change mechanisms (or mechanisms of change), mechanisms of action, behavioural change methods, theory-based techniques (or processes), and theory- and evidence-based behaviour change techniques (BCTs). Commonly used artefacts providing shared ontologies for theory- and evidence-based techniques include the CALO-RE Taxonomy (Michie, et al., 2011), the BCTT v1 93-item hierarchically clustered taxonomy (Michie, et al., 2013), and the Taxonomy of Behaviour Change Methods (TBCM) (Kok, et al., 2016). Evidence-based theoretical models and constructs are also utilised to inform the identification and selection of suitable change methods and techniques. Crucially, the selected techniques need to be evidenced as aligning with and applicable to the target health behaviour and the defined target population group. Secondly, once the techniques are selected, the team translates these methods into practical strategy applications. The team can again use methods that involve reviewing literature and empirical studies to identify ways of translating methods into practical strategies. Logic modelling techniques and tabularised templates can again be used to inform the outputs for *Step 3*.

The main outputs from *Step 3* include: the health behaviour change intervention's scope, themes, sub-themes and sequence; the Intervention Logic Model (diagram, linking change methods and practical applications with the Logic Model of Change); determinant tables (linking change objectives and change methods); method-application tables (identifies determinants, methods and theories, defines methods, describes parameters, provides application examples); the intervention plan linkage tables (linking the behavioural outcomes, determinants, change objectives, selected methods and the strategic practical applications); and documentation reporting on primary studies conducted (including study designs, ethical approval, data results, findings and analyses). Notably, none of the translated practical strategy applications deal with the digital operationalisation of techniques; activities concerning design operationalisation are carried out in *Step 4.* Nevertheless, the outputs created during *Step 3* can be consolidated together, providing the team with a preliminary intervention plan document that can be shared amongst all members of the multi- and interdisciplinary team.

### *Step 4*

*Step 4* uses a mixture of artefacts, objects and research methods, in addition to the outputs from *Step 3*, to create the conceptual design solution and materials for the digital health behaviour change intervention. Approach #1 emphasises the use of creative techniques such as brainstorming, free association, mind mapping, and metaphorical thinking to stimulate

innovate design solutions. The key aim is to use methods, artefacts and objects that can support and facilitate the operationalisation, translation and delivery of BCTs and practical strategies into intervention messages, digital design software features and technical functionalities. During this process further understanding is gained of the characteristics, strengths and limitations of the selected digital delivery platform (for instance, smartphone devices and smartphone apps). Approach #5 discusses reviewing existing commercial smartphone apps, notably of which should be applicable to the project's defined target health behaviour and target population group. Just-in-time-adaptive intervention (JITAI) technology methods can also be referenced; particularly valuable to the smartphone app delivery platform. Approach #2 also discusses the value in reviewing and utilising persuasive design models and principles to help translate techniques into persuasive software design features. This includes the use of persuasive models such as the Functional Triad, Fogg's Behavioural Model (FBM) or the Persuasive Systems Design Model (PSDM).

The main outputs from *Step 4* include: a statement on the delivery platform of choice [for example, a smartphone app; which includes a description of its characteristics, strengths, limitations and other platform-specific requirements); the (revised and extended) intervention plan (including the design structure and organisation of intervention components]; a list of the selected persuasive system design principles and techniques; a list (or table) on the intervention's messages, content and materials; method-design operationalisation tables [mapping the determinants, change methods (BCTs), practical strategy applications, parameters (conditions), the operationalised/instantiated app design features, BIT elements, and the workflow]; a list (or table) of the selected BIT elements; a detailed description of the workflow; and detailed reports on the technical implementation BIT-Tech Model (including the user profiler, the intervention planner, the intervention database repository, and the app's user interfaces). To further graphically illustrate the operationalisation of intervention techniques (components), the team can produce preliminary design artefacts and objects including: storyboards; sketches; flow diagrams; screen maps; and graphical user interface screen mock-ups. Furthermore, Approach #1 discusses the value in developing design documentation for the multi- and interdisciplinary team, which can help guide and direct members when communicating and working together during the collaborative design solution process.

### *Step 5*

All of the main outputs produced thus far during the process are used by the team to inform *Step 5*, which aims to conduct usability, feasibility and piloting studies by organising and running a series of iterative design-test-refine cycles with one or more samples of representative users (participants), a team of experts, or a group of interested stakeholders. To perform these activities, some of the new input artefacts, design objects and methods include: prototyping, usability, feasibility and pilot testing methods, guidelines and techniques; ethical protocols; recruitment procedures and documentation; and a variety of materials to design, test and refine several low- and high-fidelity prototypes (such as paper, cardboard, whiteboards, pens, colour materials, computer-aided design (CAD) software, et cetera).

The main artefacts produced during *Step 5* include: design and development documentation (tracking and describing all of the changes and refinements from each cycle); several prototypes ranging from low- to high-fidelity versions (such as storyboards; sketches; flow diagrams; screen maps; user interface screen mock-ups; simulations; interactive prototypes); prototyping and usability testing documentation (including method designs, data results, findings and analyses); pre-testing documentation (including participant recruitment and selection protocols, ethics, and procedures and guidelines for the testing methods and techniques); post-testing documentation (reporting on the data results, findings and analyses); a final health behavioural change intervention ready for implementation and summative evaluation.

### *Step 6*

The outputs from previous steps are used in *Step 6* to develop an implementation plan for the health behavioural change intervention. Approach #1 makes use of implementation and uptake frameworks (such as the RE-AIM Framework and the Interactive Systems Framework) to inform the development of the implementation plan. Approach #2 also references implementation theories (such as Diffusion of Innovations Theory) and uses the business model to guide the implementation plan's formation. The main outputs for *Step 6* are: the outcome and performance objectives for the intervention to be used in real world implementation (covering the adoption, implementation and maintenance objectives); matrices (tables) of change objectives for the intervention's implementation (linking implementation determinants with performance objectives, outcome expectations, practical applications, and feedback and

reinforcement, for adoption, implementation and maintenance) (Bartholomew Eldredge, et al., 2016, p.515-517); implementation materials (including marketing plans, awareness promotion materials, an implementation manual, and adoption manuals); support materials (including guidelines and manuals for training, education, financing, business and technical support and maintenance); an overall implementation and action plan that provides the multi- and interdisciplinary team with a shared document to guide the intervention's large-scale roll-out, adoption, deployment, implementation and maintenance.

### *Step 7*

All of the outputs produced in prior steps of the process can be used to inform the activities in *Step 7*, which is essentially focused on performing large-scale randomised controlled trials (RCTs) on the health behavioural change intervention. New summative evaluation methods and techniques are employed at this stage to inform the RCT studies, as well as study design guidelines for conducting clinical trial experiments (for example, individual randomised trials, cluster randomised trials, stepped wedge designs, and natural experiments). Approach #1 references the use of assessment criteria and frameworks to guide what will be measured during the summative evaluation studies, and how they will be conducted. The RE-AIM Framework, for instance, can be used as a template to evaluate the reach (R), effectiveness (E), adoption (A), implementation (I) and maintenance (M) of the intervention (Glasgow, et al., 2019). Approach #4 also mentions other qualitative and quantitative methods that can be used to support the summative evaluation studies, including surveys, interviews, questionnaires and focus groups. Overall, the team works to consolidate the materials, protocols and procedures relevant to long-term evaluation assessment. The main outputs for *Step 7* include: a list of the evaluation team members; outcome effect and impact effect evaluation assessments (clearly specifying the indicators and outcome measures); process evaluation assessments (covering the context, reach, delivery, reception and fidelity performance details); an overall evaluation plan for the health behavioural change intervention product (including evaluation questions, the evaluation's design, indicators and measures, study protocols and procedures to follow, details on the resources, and standard guidelines for evaluation and effect and impact result reporting such as CONSORT); formally documented reports on RCT evaluation results, lessons learned and insights gained.

### *Summary of Design Artefacts, Boundary Objects and Methods: Health Sciences Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.1.5, Figure Appendix I.2 provides a summarised graphical illustration of the key artefacts, design boundary objects and supporting methods identified as inputs and outputs into the process steps (and activities) of the five multi- and interdisciplinary approaches in the Health Sciences Perspective category.

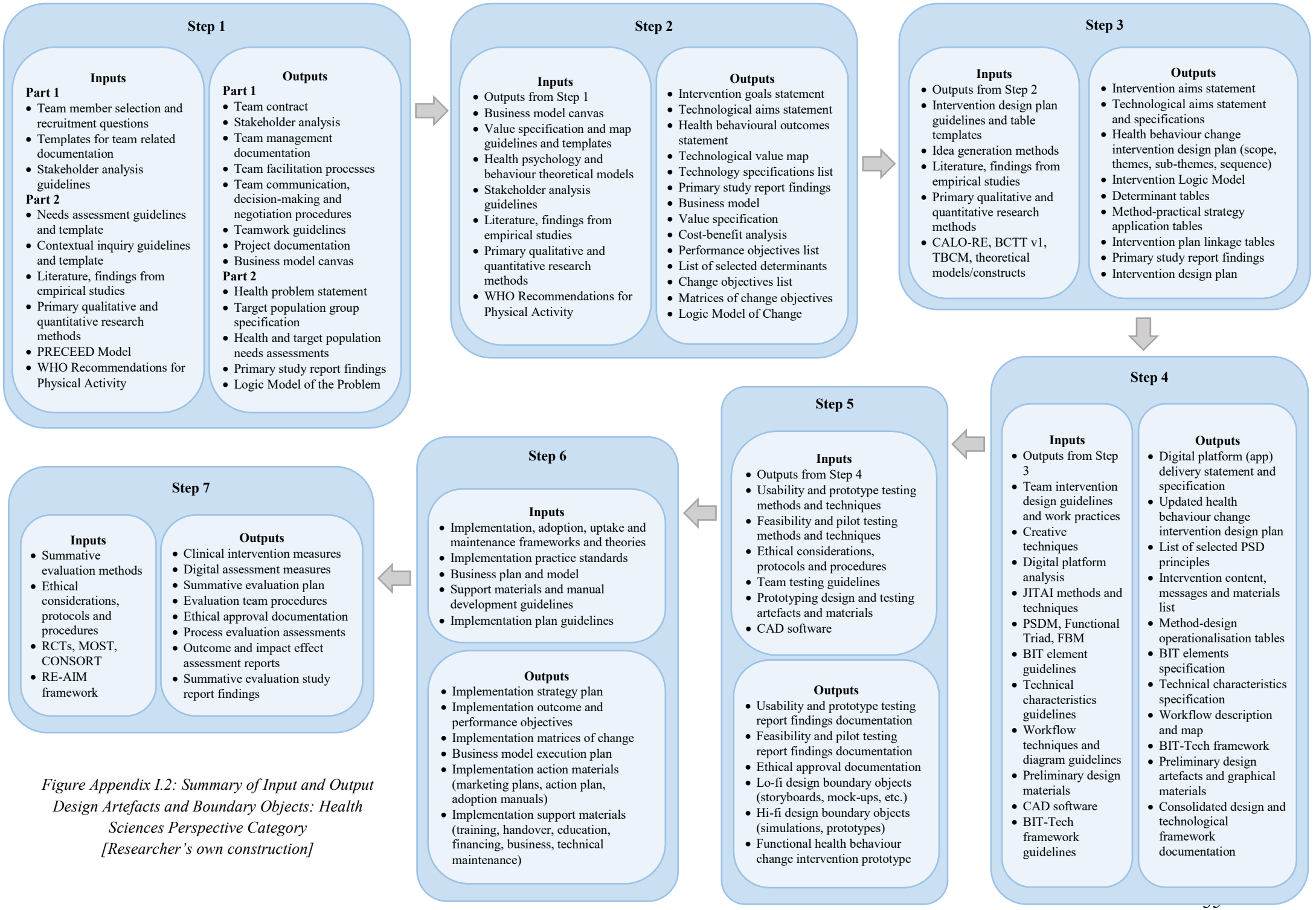



*Figure Appendix I.2: Summary of Input and Output Design Artefacts and Boundary Objects: Health Sciences Perspective Category [Researcher's own construction]*

#### 6.4.1.6 Knowledge Boundary Contributions

All five of the health sciences multi- and interdisciplinary approaches latently and explicitly recognise the value in transferring, translating and transforming knowledge across multiple heterogeneous communities of practice (or disciplinary boundaries) as a necessary and imperative requirement for the enhanced collaborative design of health behaviour change interventions. Approach #2 touches on the importance of identifying and overtly articulating heterogeneous views, values and visions of various disciplinary members (or actors) within a multi- and interdisciplinary team. Actively engaging in a process of critical reflection regarding the differences, and potential conflicts, between team members' key values, interests and visions provides a basis from which negotiations and agreement consensuses can be cooperatively worked towards (Approach #2). These notions point to the need for team members' to explicitly articulate their different disciplinary views, interpretations of meaning, aims and interests, which manifest in alternate goals, strategies, objectives and principles (Approach #2). These notions further point to the need for teams to explicitly clarify and define the intra-team power dynamics, decision-making powers, and positions of status operating within their intersecting pragmatic knowledge boundaries. Explicit articulations and clarifications allow for critical reflection, perspective-making and perspective-taking, which in turn provides a means for enabling the transfer, translation and transformation of knowledge, thereby representing a transition of knowledge across syntactic, semantic and pragmatic boundaries. Also on syntactic and semantic levels, Approach #1 briefly discusses the need for an appropriate selection and use of healthcare and medical terminology which can be commonly interpretable and understandable by team members and practitioners from outside the health sciences discipline. Approach #1 explicitly states that "language and terminology used should not limit understanding, but [should instead] promote [information and knowledge] processing that allows for greater understanding" (Bartholomew Eldredge, et al., 2016, p.459). A more abstracted and less scientific use of language and terminology becomes necessary to foster heteropraxial design practice and activity in a shared problem and solution arena.

To further enable fruitful communication and knowledge transfer, translation and transformation across boundaries of heterogeneous, yet intersecting, communities of practice, multi- and interdisciplinary teams should aim to clearly identify, organise and coordinate the different roles, responsibilities and decision-making powers of participating actors. Approach #2, for instance, emphasises concerns regarding the lack of "clear information … about … the

roles and responsibilities of different stakeholders [that is, multi- and interdisciplinary team members] at different stages of the development process", and how this directly affects the outcome of a digital health behavioural change intervention product (van Gemert-Pijnen, et al., 2011, p.10-11). In light of this concern, Approach #2 advocates for the creation of participatory design methods, shared collaborative processes and mediating objects that outline the roles, responsibilities and decision-making powers of actors whilst simultaneously incorporating and coordinating the diversity of heteropraxial activities and knowledge and skill contributions that each actor offers. Some of this information is often demarcated and outlined in the formalised team and project documentation created in the initial part of the first step in the multi- and interdisciplinary process.

In comparison to Approaches #1 and #2, Approaches #3 and #4 explicitly recognise the importance of cross-boundary communication, collaboration and cooperation between diverse practice communities, yet they fail to discuss how these engagements and exchanges can be achieved in practice. Approaches #3 and #4 fail to discuss knowledge transfer, translation and transformation, yet overtly acknowledge that there is "little to guide researchers or practitioners on how best to develop [health behaviour change] interventions in practical, logical, evidence-based ways to maximise likely effectiveness" (Wight, et al., 2015, p.1). Again, this points to the need for artefacts and objects that on the one hand can provide support and structure for delineating of roles, responsibilities, knowledge, expertise, skills and activities of heterogeneous team members, and on the other hand, can support cross-boundary communication and collaborative, cooperative and coordinated heteropraxial teamwork. Approach #5 discusses the BIT Model (Approach #7) as a valuable theoretical framework (hence, artefact) for "support[ing] the communication between developers and [health] behavioural scientists" and for "aid[ing] the translation of BCTs into [technical] elements, characteristics and workflow" (Direito, et al., 2018, p.343).

When designing, developing and evaluating digital health behaviour change interventions, Approach #4 underscores that "interventions are best developed through collaborations between interdisciplinary teams", yet "little guidance exists for … explain[ing] the essential stages of intervention development" (Wight, et al., 2015, p.1). This argument reinforces the need for clearer practical process and activity guidelines for multi- and interdisciplinary heterpraxial design work within shared problem and solution spaces. In light of this instrumental issue, Approach #2 highlights the valuable and integral need for teams to adopt

"a multi-perspective view" that accounts for different team members' alternate values, visions, concerns, proposed solutions and outcome measures with regard to design, development and evaluation activities and processes (van Gemert-Pijnen, et al., 2011, p.7).

Overall, four of the five health sciences multi- and interdisciplinary approaches (with the exception of Approach #5) places a heavier weighting on the knowledge, skills, expertise, activities and contributions offered from health science and health psychology disciplines. Approach #5, in contrast, integrates a comparably more equal and mutual weighting between health science knowledge and digital/technological knowledge contributions. Critical thought trial analyses and judging-making processes reveal that while health science and health psychology knowledge provide fundamental and essential contributions to the digital health behaviour change intervention development process, the multi- and interdisciplinary team as a whole cannot favour health science/psychology knowledge over digital technology/information systems knowledge, as this results in the biasing of power and status at the expense of a holistically effective product outcome. On an alternative final note, none of the five multi- and interdisciplinary approaches in the Health Sciences Perspective category discuss the managing of dependencies and novelties across knowledge boundaries and within shared knowledge spaces, nor do any of them examine the necessity for trade-offs and sacrifices as a means to transform and generate new knowledge within a multi- (and inter-) disciplinary evolving arena.

#### 6.4.1.7 Limitations and Lessons Learned

Limitations, gaps, weaknesses and lessons learned can be identified across all five of the multi- and interdisciplinary approaches in the Health Sciences Perspective category. The following short discussion does not provide an extensive critical analysis on all possible limitations or lessons learned, but instead touches on a few noteworthy points given the adopted theoretical lens (boundary object perspective) utilised to frame the conducted cognitive thought trials and judgement-making processes. With this being said, an initial cross comparison reveals a weakness in that four of the approaches (with the exception of Approach #5) are applicable to all complex health interventions in general, and therefore include an extensive range of health contexts spanning medical conditions, healthcare services, emergency departments, hospitals, nursing, pharmaceutics, and more. This is a weakness in that it fails to specify the particularised details relevant and necessary to certain contexts, such as health promotion interventions for behaviour change in particular. Associated with this limitation is that three approaches (namely

Approaches #1, #3 and #4) are generalised to guide the development of health promotion interventions across all possible delivery platforms, which, for example, can range from print materials (such as magazines, newsletters, brochures and posters) to roadside billboards, radio and public service announcements, television advertisements, and mobile smartphone applications. Approaches that are generalised to all possible platforms fail to account for the evident and nuanced characteristics and capabilities of certain modes of intervention delivery, which, when disregarded or overlooked by intervention designers and developers, can significantly impede the potential effectiveness of a given health intervention. In comparison to Approaches #1, #3 and #4, Approach #2 is scoped to the eHealth technology context as a whole. Although, despite being more platform-particularised than the other three approaches, Approach #2 remains relatively generalised as it encompasses a broad range of technological and digital platforms, such as electronic health records, electronic medical records, personal health records, websites, and smartphone apps; all of which possess different technological and digital characteristics, capabilities and limitations. In contrast, unlike the other four health sciences approaches, Approach #5 is the most particularised to the mobile smartphone app platform, and is cognisant from the early commencement of the intervention design and development project that the characteristics, capabilities, limitations and particularities of the chosen mode of delivery are carefully noted and accounted for. Furthermore, Approach #5 is the only approach of the five that provide guidance for translating and operationalising intervention strategies (BCTs) into BIT elements and instantiated digital app design features. Approaches #1, #2, #3 and #4, in comparison, are limited in their guidance for operationalising and instantiating BCTs into digital interactive design features. This is a noteworthy weakness as failure to account for detailed explanations for how digital app design features will be instantiated significantly hinders the ultimate design, and subsequent potential effectiveness, of the mHealth behaviour change intervention app. Approach #5's process therefore provides valuable lessons learned concerning its specific platform-focus, and moreover, provides further additional insights and lessons learned regarding its case application to the mHealth physical activity behaviour change *TODAY* app (Direito, et al., 2018).

Another weakness of Approaches #1, #2, #3 and #4 is their all-encompassing socioecological health intervention level focus, which incorporates all influential factors identifiable across individual (intrapersonal), social (interpersonal), community, organisational, national (societal) and supranational levels. While this is a strength for large-scale multi-level complex public health promotion interventions, it is a weakness when designing and developing self-

management consumer health promotion behaviour change intervention apps intended for delivery on a dual intra-(primary)interpersonal socioecological level. Once again, in sharp contrast to the other four health sciences approaches, Approach #5 is particularised to this dual-socioecological level focus, and therefore provides valuable insights and lessons learned for the smartphone app context. On another note, Approaches #1, #2, #3 and #4 are comparably more time and resource intensive than Approach #5, especially considering the extensive input required to design, develop and evaluate the health interventions, often taking up to several years before completion. In keeping with the mention of resource demands, all five health sciences approaches are limited in that they require (and implicitly assume) all of the multi- and interdisciplinary team members to possess a sufficient, yet significant, amount of specialist knowledge, skill and expertise in order to interpret, make-sense-of, understand and apply the respective steps/stages and activities of their proposed processes. This implies a need for considerable past experience and substantial tacit knowledge and understanding, which in turn discourages and hampers the adoption, use and application of the five approaches by inexperienced, untrained and amateur health (promotion) behaviour change app intervention designers and developers.

Regarding the nature of the health sciences approaches, all five of them are limited in that their processes do not advocate for or prescribe a rapid or cyclical approach to intervention design and development. This is a noteworthy weakness and limitation considering given the rapid and agile nature of the constantly evolving, adapting and advancing mobile device and smartphone app industries and environments. Related to the nature of the approaches are the perspectives they offer. A notable lesson learned is offered by Approach #2 in its incorporation of a business perspective which considers elements concerning the commercial, product development and consumer markets. A business perspective is valuable in its applicability to the commercial smartphone app industry and consumer app market stores (such as the Android Google Play and Apple iOS stores) which provide the main platforms for publically releasing and downloading consumer mHealth apps. Also related to the approaches' natures and perspectives are their proposed and prescribed steps, stages, components and activities. In terms of notable limitations, the five approaches stemming from a predominant health sciences arena all favour traditional randomised controlled trails (RCTs) over other summative evaluation methods. This is a weakness considering the rapidly changing and evolving nature of the smartphone app field, particularly considering that traditional clinical RCTs are renowned for their notoriously long evaluation timeframe, and have been reported to taking

anywhere from a minimum of 2 years (Piantadosi, 2017) to an average of 5.5 years (Pham, Wiljer and Cafazzo, 2016) to perform, and at times, can take up to six or seven years for full publication and dissemination (Jacobs and Graham, 2016). The extensive timeframes required to perform quality RCTs ultimately leaves an mHealth app "obsolete by the time the trial [period] is completed" (Mummah, et al., 2016, p.5). Other limitations of traditional RCTs include their purely positivistic assumptions, their rigid "lock down" approach to testing, and their intensive time, effort, cost and resource demands; all of which is regularly argued as incompatible and impractical for properly evaluating the effectiveness and efficacy of mHealth behaviour change intervention apps (Collins, et al., 2005; Mohr, et al., 2015; Jake-Schoffman, Silfee and Waring, 2017; Blandford, et al., 2018; McKay, Slykerman and Dunn, 2019). Further details and explanations of the criticisms for employing traditional RCTs as the gold standard for summatively evaluating mHealth apps can be referred to in the discussion under *Step 6* of Subsection 6.4.2.4. Lastly, a critical cross-comparative analysis of all five multi- and interdisciplinary health sciences approaches reveals none of them as recognising or discussing any concepts or constructs regarding community of practice theory, boundary object theory and knowledge boundary theory. On the one hand, this demonstrates a noteworthy gap in the existing knowledge base. On the other hand, this verifies that the proposed boundary object view (as a theoretical framework/lens) offers a novel contribution to the current knowledge base concerning the newly emerging multi- and inter-disciplinary mHealth behaviour change intervention app arena. This newly proposed alternative theoretical framework (lens) is advantageous in its novelty, yet disadvantageous in that the identifiable and extractable comparative and thematic analysis findings from the five health science multi- and interdisciplinary approaches are, for the most part, latent and implicit, hence inherently lessening and limiting the richness of the generated themes. On a closing note, a handful of other noteworthy limitations, gaps, weaknesses and lessons learned can be referred to in Table A under Appendix H; although, to reiterate, these points are neither copious nor comprehensively extensive.

### 6.4.2 A Critical Analysis of Multi- and Interdisciplinary Approaches: An Information Systems and Technology Perspective

Multi- and interdisciplinary approaches offering a predominant information systems and technological perspective are of paramount importance to review and critically analyse, especially considering their knowledge contribution to understanding the digital technology platforms through which health (promotion) behaviour change interventions are delivered. Put

simply, they provide insight into the mode of intervention delivery. Multi- and interdisciplinary approaches focusing on mobile devices and apps in particular are instrumental to informing the development of the interdisciplinary framework artefact (Chapter 7). Reviewing these approaches provides insight into the various ways health behavioural change interventions can be designed, developed, evaluated and delivered digitally by multi/interdisciplinary collaborating teams. Reviewing these approaches provides further understanding of the general strengths, challenges and limitations associated with delivering health interventions via digital technology platforms. The Information Systems and Technology Perspective category specifically covers approaches intended to support the design, development and evaluation of: digital health interventions, eHealth interventions and complex digital health interventions (Approaches #7 and #8); mHealth and mHealth app interventions (Approaches #6, #7, #9, #10, #11 and #12); and persuasive technology/systems and health behavioural change support systems (Approaches #7 and #10). Overall, the seven information systems and technology approaches provide insight into the main themes and subthemes that are necessary and relevant to the mHealth behaviour change intervention app design, development and evaluation context.

The template criteria (Table 6.5) is used to critically analyse each of the seven approaches. Table B in Appendix H provides a full detailed summary analysis of the information systems and technology approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the seven approaches, presented in a written report discussion. Box 6.5 identifies the five multi- and interdisciplinary approaches classified in the Information Systems and Technology Perspective.

- **Approach #6** Development and Evaluation Process for mHealth Interventions
- **Approach #7** The Behavioural Intervention Technology (BIT) Model for eHealth and mHealth Interventions
- **Approach #8** IDEAS (Integrate, DEsign, Assess and Share) Framework and Toolkit for Digital Health Behaviour Change Intervention Development
- **Approach #9** mHealth App Intervention Development Process
- **Approach #10** Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps
- **Approach #11** mHealth Intervention Design Process for Behaviour Change
- **Approach #12** Agile Development and Evaluation Approach for mHealth Apps

*Box 6.5: Multi- and Interdisciplinary Approaches: Information Systems and Technology Perspective [Source: Researcher's own construction]*

#### 6.4.2.1 Aims and Contexts of Information Systems and Technology Perspective Approaches

The seven multi- and interdisciplinary approaches categorised in the Information Systems and Technology Perspective share a common aim: *to guide designers and developers through a process, comprising a series of steps and activities, that ultimately leads to the development and release of a technology-based health intervention*. Six of the seven approaches, namely Approaches #6, #7, #9, #10, #11 and #12, aim to guide the design and development of mHealth intervention apps specifically. Approach #7 provides a design and development process for both mHealth and eHealth interventions. Approach #8, in comparison, aims to guide the design and development of health behaviour change interventions for digital technologies overall, although Mammah, et al. (2016) explain that this includes mHealth intervention apps together with eHealth and other digital technologies.

Five of the seven approaches (with the exceptions of Approaches #9 and #12) have been applied to the physical activity health (promotion) behaviour change context. Several studies have employed these multi- and interdisciplinary approaches when designing, developing and evaluating physical activity behaviour change intervention apps in particular. Example apps include, namely: *MyFitnessPal* (Mohr, et al., 2014), *HelpMeDot!* (Matthews, et al., 2017) and *TODAY* (Direito, et al., 2018), which all used Approach #7; *Puzzle Walk* (Lee, et al., 2018), which used Approach #8; and *30 Day Fitness Challenge*, *Step Counter*, *Nike+ Running*, *Fitocracy* and *Endomondo* (Geuens, et al., 2016; 2019, Online Toolkit), which were all examined using Approach #10. The two exceptions, Approaches #9 and #12, when first developed, were aimed at targeting the healthy lifestyle and pharmaceutical mHealth app contexts, respectively. Notably, Approach #9 is aimed at the healthy lifestyle context in general, targeting physical activity together with healthy eating, hygiene and smoking cessation. Approach #9, when originally developed, was used for the creation and evaluation of the *Health Heroes* app, which has subsequently been released on the public Android Google Play and Apple iOS consumer app stores. In contrast to the other six approaches, Approach #12 was first developed and applied in the clinical pharmaceutical mHealth app context, although lessons learned from the approach offer generic contributions valuable to the mHealth physical activity behaviour change intervention app context.

With regard to target audience, all seven approaches have been employed and used for informing the design, development and evaluation of mHealth intervention apps aimed at the

dual intra-interpersonal socioecological intervention levels. Overall, all of the seven approaches aim to support multi- and interdisciplinary collaborative team efforts, include theory and evidence-based processes, and describe using methods, artefacts and objects to facilitate and mediate collaborating team's efforts. Furthermore, all seven approaches harness and/or draw from existing theoretical models, and five of the seven approaches (with the exceptions of Approaches #7 and #10) aim to provide digital health and mHealth intervention development process guidance based on existing multi/interdisciplinary approaches. Approaches #6 and #9, for instance, are developed by incorporating components and themes from *Intervention Mapping* (Approach #1). Notably, Approach #8 reviews and/or draws from seven existing process approaches, including Approaches #2, #3, #6, #13 and #20.

For purposes of length, the Information Systems and Technology Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.2.2 to 6.4.2.7 are extracted to Appendix I. One summary table and two summary figures for the Information Systems and Technology Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

#### 6.4.2.2 Actors and Community of Practice Members

Overall, the seven selected multi- and interdisciplinary approaches reviewed in this critical analysis identify a broad range of actors and community of practice members involved in the collaborative digital health intervention development team. Apart from Approach #12, six approaches make explicit reference to participating actors as "stakeholders". Only three of the approaches (Approaches #9, #10 and #11) refer to some actors as "practitioners", such as the latter two (#10 and #11) who mention "healthcare" and "health" practitioners, respectively. Most approaches also recognise particular third-party stakeholders, for example: Approach #6 identifies funders, providers and wireless companies; Approach #7 mentions the healthcare system; Approach #8 identifies public and private sector organisations, and industry partners (although it does not further elaborate on which partners); Approach #9 recognise local authorities, service commissioners and case workers; Approach #10 makes brief mention of government and health insurance providers; and Approach #12 discusses industry partners, funders, policy makers, legislative and regulatory officials, and government agencies. Approach #11, in contrast, does not recognise any of these third-party stakeholders. However, on an important note, Approach #11 together with Approach #9 explicitly identify partnerships and collaborations with the commercial smartphone app industry, which suggests working with

consultants at consumer app market companies. All seven of the multi- and interdisciplinary approaches make reference to research groups, academic institutions and researchers, with Approaches #8, #9 and #10 mentioning "researchers" six to sixteen times in their publication articles. In addition, Approaches #8 and #12 highlight the value of forming strategic academic-industry partnerships between researchers and public or private companies. Their touching on the value of potential partnerships, however, does not classify them in the third Partnership Perspective category, since their approaches are not based on, or grounded in, participatory and partnership methods. In terms of team formalities, none of the seven approaches discuss the need for actors and members to mutually and formally develop and sign team contract agreements.

On another note, Approaches #7 and #12 use terms related to digital health "intervention designers" and "intervention developers" to describe any multi- and interdisciplinary team actor involved in a given digital health intervention development process. Markedly, Approaches #7, #9, #10 and #11, also use the same terms "designers" and "developers" to describe information systems designers and developers, and app designers and developers. This represents a conspicuous difference, and potential conflict, of two fundamentally distinguishable worldview perspectives, held by the health sciences and information systems disciplines, respectively. The flexibility of use and interpretation of the terms "designers" and "developers" as a reference to distinctly different disciplinary actors represents a lack of consensus terminology in the shared multi- and interdisciplinary spaces. Concerningly, this opens up opportunities for potential misunderstandings and engagement conflicts between heterogeneous multi- and interdisciplinary team members. On a different note, Approaches #7, #8, #9 and #12 make reference to software and system engineers as being involved in the multi- and interdisciplinary teams, whereas the other three approaches do not recognise these actors. None of the seven approaches identify or mention team facilitators, or project leaders or project managers who can be tasked with responsibilities in organising, managing and coordinating the multi- and interdisciplinary team members. Approach #9 does, however, make brief mention of smartphone app company consultants as facilitating one specific stage in a ten-step process: that is, leading the translation of health behaviour change technique (BCT) intervention components into mHealth app design features. Six of the seven approaches, with the exception of Approach #11, make reference to the involvement of various professional actors and disciplinary experts as valuable to the digital health intervention development process, since they can contribute a heterogeneity of specialist knowledge, skills and expertise

from different perspectives. With regard to mentioning specific actors with particular disciplinary expert knowledge and skills, Approach #6 identifies multi- and interdisciplinary team members to include: medical experts; public health intervention experts; mHealth intervention developers; wireless companies; funders; and other providers. Approach #7 identifies team members to include: health behavioural scientists; health psychologists; design engineers; system engineers; technologists; mHealth app designers; mHealth app developers; persuasive system designers; user-centred designers; human-computer interaction specialists; human factors engineers; and software engineers. Approach #8 identifies team actors to include: user-centred designers; programmers; health behavioural scientists; behavioural intervention researchers; industry partners; academics; designers; engineers; mHealth app designers; mHealth app developers. Approach #9 mentions: case workers; weight management service commissioners; community programme managers; parents; health psychologists; nutrition experts; physical activity experts; mobile and smartphone app experts; software engineers; usability designers; user experience designers; and consultants from a commercial app company. Approach #10 explicitly mentions two team members only: mHealth app designers and mHealth app developers; but latently discusses health psychologists; motivational psychologists; health behaviour change specialists; and persuasive system designers. Similar to Approach #10, Approach #11 only identifies a few team members explicitly: user-centred designers; mHealth intervention designers; mHealth app designers; and mHealth app developers; and implicitly refers to health behavioural theorists and health psychologists. The last Information Systems/Technology approach, Approach #12 explicitly identifies multi- and interdisciplinary team members to include: project team members; test engineers; academics; regulatory officials; developers [used in general as an umbrella term]; scientists [used as a general term]; healthcare providers; and mHealth product developers; and latently refers to user experience designers; human-centred designers and specialists; user-centred designers; and health behavioural intervention designers and developers.

All seven multi- and interdisciplinary approaches discuss indirect and direct engagements and involvements with target population (end user) representatives at various stages of the intervention design, development and evaluation process. Target users are generally referred to in these approaches in an indirect rather than direct form, as participants who partake in, and provide feedback on, piloted app prototypes and final app products. Indirect participation, for instance, is discussed in Approaches #6, #8, #9, #11 and #12, which emphasise target user involvement in the (first) initial and formative stages of a digital health intervention

development process, generally as a means for conducting qualitative research on users' preferences and needs assessments. Analogous to the discussion in the Health Sciences Perspective category – specifically under Subsection 6.4.1.2 – these references to target end user participant involvements are not intrinsically grounded in holistic partnership and participatory design approach orientations to digital health and mHealth intervention development, and hence are not classified under the third Partnership Perspective category.

#### 6.4.2.3 Perspectives, Underlying Theories, Models, Tools and Existing Approaches

In the Information Systems and Technology Perspective category, six of the seven multi- and interdisciplinary approaches adopt a health promotion approach to intervention development, and the same six are all underpinned and informed by health psychology theory. Approach #12, in contrast, does not adopt either of these two perspectives. Five approaches, namely Approaches #7, #8, #9, #10 and #11, integrate perspectives from the field of health behavioural sciences. All seven approaches adopt a socioecological approach to digital health behavioural change intervention development, although Approaches #6, #7, #8, #10 and #11 focus on targeting the individual and interpersonal socioecological levels, while Approach #9 intervenes at the individual and interpersonal levels as well as the community level. Approach #12 is the only approach of the seven reviewed that adopts a much broader multi-level socioecological approach by considering and integrating environmental factors from the organisational and societal levels. The approach incorporates national government policies and regulatory standards such as the published guidance on Mobile Medical Applications (U.S. Food and Drug Administration, 2015) enacted by the Food and Drug Administration (FDA) in the United States of America. Five of the seven approaches, with the exceptions of Approaches #7 and #10, incorporate aspects of a participatory approach, although applied in different ways. Approach #6, for example, adopts a cross-cutting theme that focuses on "target population involvement", whereas Approaches #8 and #9, for instance, involve user participants at specific stages of the development process. Associated with a participatory approach is the user-centred design approach. A user-centred design approach is incorporated into Approaches #6, #8, #9, #11 and #12. Dissimilarly, this approach is not considered in Approach #10, nor in Approach #7, of which in the article on the latter, the authors explicitly state that the BIT Model does not integrate user-centred design processes. Approaches #8 and #12 are the only two to consider principles of human-centred design, which notably, is distinguishable from principles of user-centred design. Associated with user-centred design, user interface design and human-

computer interaction design perspectives are incorporated in Approaches #7, #8, #10, #12 and #9 (albeit latently and not explicitly in #9). Another design approach, namely design thinking, is considered in Approach #8 and briefly mentioned in Approach #12. User experience design is explicitly incorporated in Approaches #8, #9 and #12, and is latently acknowledged in Approaches #10 and #11, although is not recognised in Approaches #6 and #7. These various design approaches generally have origins in the field of information systems, which filters into the systems thinking approaches that are incorporated in the same five approaches (Approaches #7, #8, #9, #10 and #12). Related to the systems thinking perspective, software engineering approaches are explicitly recognised in Approaches #7, #9, #10 and #12, although latently incorporated in Approach #8. One approach, Approach #9, intriguingly included UML (Unified Modelling Language) techniques, which is traditionally used in information systems, systems engineering and software design. More specifically with regard to the Information Systems and Technology Perspective category, mHealth intervention and digital technology intervention perspectives are integrated in all seven multi- and interdisciplinary approaches. Six of the seven approaches, with the exception of Approach #12, are orientated towards healthy lifestyle (behaviour) modification and wellbeing management, and fives of the approaches (with the exceptions of Approaches #9 and #12) discuss physical activity as a targeted health behaviour. Persuasive technology and persuasive systems design perspectives are only integrated in Approaches #7 and #10, and not the other five approaches. Granted, Approach #9 recognises "persuasion" as a behaviour change technique; however, this stems from the disciplines of health psychology and health behavioural sciences, and not persuasive technology or persuasive systems design. Furthermore, only two of the multi- and interdisciplinary approaches, specifically Approaches #9 and #10, incorporate principles, techniques and models of gamification into their approaches. On a separate, yet valuable note, the commercial smartphone app industry and consumer app markets are included in Approaches #11 and #12. Recognising and fusing the commercial app industry and consumer app market is imperative for this research project, particularly since the topic of focus is positioned with the field of Consumer Health Informatics, which advocates for the proactive self-management of individuals' health and wellbeing (discussed extensively in Chapters 3 and 4).

Theoretical bases underpin all seven of the multi- and interdisciplinary approaches reviewed in the Information Systems and Technology Perspective category. All of the approaches review existing theoretical frameworks, approaches and models from a diversity of fields related to

the design, development and evaluation of mHealth and digital health behaviour change interventions. Approach #6, for instance, lays a "theoretical basis" as directly underpinning a five-step process. Informed by a review of the Intervention Mapping (IM) protocol (Approach #1), Approach #6 stipulates this "theoretical basis" as a cross-cutting theme that is integral to the foundation of mHealth intervention development. Approach #7 reviews and critiques theoretical models, before incorporating strengths of three specific theoretical models in the BIT Model. Approach #8 reviews and incorporates several existing theories and approaches to inform the development of the IDEAS Framework, which the authors describe as "the best combination of approaches available" (Mummah, et al., 2016, p.1). Approaches #8, #9, #10, #11 and #12 similarly review and incorporate aspects of existing theoretical models and approaches. With respect to individual and interpersonal theories, six of the seven approaches (besides Approach #12) include a few evidence-based health psychology theories and models which are frequently discussed in digital health behaviour change intervention research (Hekler, et al., 2016; van Gemert-Pijnen, et al., 2018; Klonoff, 2019), and in physical activity mHealth behaviour change intervention studies in particular (Kermarrec, et al., 2014; Maberry, 2016; Voth, Oelke and Jung, 2016; Baretta, et al., 2019). Some of the theories discussed and included in the approaches are: social cognitive theory (SCT); self-determination theory (SDT); self-regulation theory (SRT); self-efficacy theory (SET); social learning theory (SLT); theory of reasoned action (TRA); theory of planned behaviour (TPB); goal setting theory (GST); theories of social support (SS); the transtheoretical model (TTM); the health belief model (HBM); the diffusion of innovations technology model (DIT); the elaboration likelihood model (ELM); the integrated behaviour change model (IBCM); and the integrated behaviour model (IBM). An important contribution is articulated in the paper on Approach #7, which argues that despite these popular existing psychological theories being partially informative for understanding and predicting changes in humans' attitudes and behaviours, they lack consideration for factors that are distinct and important to the digital technology and mobile smartphone platforms. For the exact identification of which individual and interpersonal theories are identified in Approaches #6 to #11, refer to Table B in Appendix H. On another note, Approaches #7 and #8 are the only two multi- and interdisciplinary approaches that identify and integrate theory on just-in-time adaptive interventions, while Approach #10 latently acknowledges just-in-time adaptive technology. Just-in-time adaptive interventions (JITAIs) have shown to be an important consideration when designing effective mHealth behaviour change app interventions, particularly in the contexts of physical activity and

sedentary behaviour (Muller, Blandford and Yardley, 2017; Nahum-Shani, et al., 2018; Direito, et al., 2019).

Theory-informed and evidence-based (health) models and tools are significantly valuable for assisting intervention designers and developers when developing mHealth behaviour change app interventions. Five of the seven approaches, specifically Approaches #7, #8, #9, #10 and #11 identify two coding taxonomies: the CALO-RE Taxonomy and the BCTT v1. None of the seven approaches acknowledge or discuss a taxonomy of development, namely the Taxonomy of Behaviour Change Methods (TBCM). The Theoretical Domains Framework (TDF) is adopted and utilised only in one of the seven approaches (Approach #9). Approach #12 is the only approach to mention the CONSORT-EHEALTH checklist. The Behaviour Change Wheel (BCW) and the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model) is included in Approaches #9, #10 and #11. None of the approaches mention the PRECEDE-PROCEED Model. Approach #7 reviews and incorporates aspects of the Ritterband Model. Approach #11 is the only approach that discusses the APEASE Criteria (Affordability, Practicability, Effectiveness, Acceptability, Side Effects and Equity), and the Health Information Technology Usability Evaluation Model (Health-ITUEM), and their value as validated tools for evaluating mHealth behaviour change intervention apps. Approach #8 briefly mentions the Health-ITUEM, but does not incorporate it in the approach. Approach #10 is the only approach to discuss the Functional Triad (a spearheaded taxonomic contribution to the field of persuasive technology), although both Approaches #7 and #10 integrate Fogg's Behavioural Model (FBM) and the Persuasive Systems Design Model (PSDM). Approach #6 does not discuss or employ any of the (health) models or tools discussed here.

Five of the seven approaches, specifically Approaches #6, #8, #9, #11 and #12, discuss and draw from existing multi- and interdisciplinary approaches. Approach #6 mentions the Intervention Mapping (IM) protocol (Approach #1), although it does not describe how the protocol can be employed in the process of the approach. Approach #9, in contrast to Approach #6, details and demonstrates how the IM protocol (Approach #1) can be utilised when carrying out specific steps within the approach's process. The article on Approach #9 also recognises other existing approaches, namely Approaches #3, #6 and #7, although it does this with the intention of comparing them to Approach #9, rather than using them to inform the approach's development. Approach #8 reviews Approach #2 as an existing approach, but does not further explain whether it is incorporated into the approach's development. In comparison to this, the

authors do explicitly articulate that Approach #8 incorporates aspects of Approach #3, "builds on" Approach #6, and "draws on strengths" of Approaches #13 and #20 (Mummah, et al., 2016, p.6). Contrary to Approach #8, Approach #7 is not based on or informed by any existing multi- and interdisciplinary approaches; although it does review three existing theoretical models, namely the Ritterband Model, the FBM and the PSDM. The paper on Approach #12 is similar to this in that it reviews an existing multi- and interdisciplinary approach (Approach #8), but not with the intention to use it to inform the development of Approach #12. Approach #12, nevertheless, provides a valuable contribution that none of the other six approaches offer, and that is the base integration of the Agile Systems (or Software) Development Lifecycle; an approach that provides an iterative, rapid and flexible process for mHealth intervention design, development and evaluation. Lastly, unlike the other six approaches, Approach #10 does not reference or adopt any existing multi- and interdisciplinary approaches.

#### 6.4.2.4 Nature of Approaches and Process Steps and Activities

*Nature of the Approaches*

Seven of the multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category share characteristics of being iterative and evidence-based. Six approaches (with the exception of Approach #12) share the quality of being theory-based, and six approaches (with the exception of Approach #10) are cumulative in nature. The authors of Approach #6, for example, describe their six-step process as iterative and cumulative; explicitly explaining that the "findings from each step inform subsequent steps" (Whittaker, et al., 2012, p.18). Four of the seven approaches, namely Approaches #6, #8, #9, #11 and #12, are described by their authors as systematic. Four approaches, specifically Approaches #7, #8, #9 and #12, are cyclical in nature. In addition, all four of these can be described as possessing "rapid cyclical" qualities, meaning that team members carry out cyclical iterations of particular steps (stages or phases) within a given process quickly, in relatively short timeframe intervals. The manner of cyclical behaviour may vary depending in the approach. For instance, on the one hand, Approach #9 stipulates that iterative "feedback loops" (which can be referred to cycles) function between the three stages of the process, whereby each stage comprises a few steps each. On the other hand, iterative feedback loops (or cycles) can function within – rather than between – particular steps (stages or phases) of a process. Approach #8, for example, discusses rapid prototyping development in phase five, and rapid user feedback gathering in phase 6, of their ten-phase process. In keeping with the nature of feedback loops, the authors

of Approach #12 also describe their process has encompassing "continuous" iterative feedback cycles. With regard to other characteristics, Approach #8 can be described as "flexible", given that the multi- and interdisciplinary team members can carry out stages and phases in a variety of ways. To clarify, Approach #8 comprises four stages and ten phases: stage one has three phases; stage two has four phases; stage three has two phases; and stage four has one phase. The authors explain that, depending on the strengths, skills and expertise of the given multi- and interdisciplinary team members, stages and phases can be applied flexibly "pursuing multiple stages in parallel, in combination, more than once, and/or iterative, as new directions are explored and refined" and that the ten phases of the IDEAS Approach "are more like a system of overlapping spaces, rather than a sequence of orderly steps" (Mummah, et al., 2016, p.5). This nature also suggests a non-linear characteristic of Approach #8. Similarly, Approach #12 is also described by its authors as non-linear. In comparison to these two approaches, Approaches #6 and #11 represent linear qualities. Approach #9 also has linear aspects to certain stages of its process, such as the linear progression of steps one to four in stage one, steps five to eight in stage two, and steps nine to ten in stage three; where the steps in each stage build upon one another. Moreover, the authors of Approach #12 explicitly describe their process as "dynamic", although the authors' descriptions of Approach #8 can be latently referred to as dynamic as well. On a final note with regard to nature and characteristics, Approach #10 is the only approach of the seven (in the Information Systems and Technology Perspective category) that is explicitly described as "pragmatic" by its authors.

### *Process Steps and Activities*

All seven of the multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category provide a series of steps (also referred to as stages, phases or components) that constitute prescribed processes for guiding intervention designers and developers in developing technology- or digitally-based health interventions. The various process steps (stages, phases or components) for each information systems and technology approach is provided Table Appendix I.2. For each of the seven processes, Table B in Appendix H provides detailed descriptions, sub-steps and activities for each step, as well as the methods, tools and artefacts used and/or produced at each step.

*Table Appendix I.2: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Information Systems and Technology Perspective Category [Researcher's own construction]*

| Approach #6 | Approach #7 | Approach #8 | Approach #9 | Approach #10 | Approach #11 | Approach #12 |
|---|---|---|---|---|---|---|
| Step 1:<br>Conceptualisation | **Theoretical Level:<br>Conceptual Framework** | **Stage 1: Integrate** | **Stage 1: Understanding the Problem and User Preferences** | The Dyadic Lenses:<br>Core Elements and Concepts | Stage 1:<br>Conceptualisation | **Project Stage** |
| Step 2:<br>Formative Research | Component 1:<br>"Why":<br>Intervention Aims | Phase 1: Empathise | Step 1:<br>Define the Problem | Left of the Dyad:<br>Lens of Features | Stage 2:<br>Formative Research and Pre-Testing Activities | Phase 0:<br>Project Identification |
| Step 3:<br>Pre-Testing | Component 2:<br>"How" (Conceptual):<br>Behavioural Strategies | Phase 2:<br>Specify | Step 2:<br>Select the Target Behaviour | Right of the Dyad:<br>Lens of Theories | Stage 3:<br>Pilot Trials | **Clinical Development Stage** |
| Step 4:<br>Pilot Study | **Instantiation Level:<br>Technological Framework** | Phase 3:<br>Ground | Step 3:<br>Specify the Target Behaviour | The Dyadic Set of Lenses:<br>Cross-Links | Stage 4:<br>Evaluation Trials | Phase 1:<br>User-Experience Design, Development and Alpha Testing |
| Step 5:<br>Randomised Controlled Trials (RCTs) | Component 3:<br>"What":<br>BIT Elements | **Stage 2: Design** | Step 4.1:<br>Understand the Problem | | | Phase 2:<br>Beta Testing |
| Step 6:<br>Qualitative Follow-Up | Component 4:<br>"How" (Technical):<br>Characteristics | Phase 4:<br>Ideate | Step 4.2:<br>Understand User Preferences for Technological Components | | | Phase 3:<br>Clinical Trial Evaluation |
| **Steps 1 to 6:<br>Cross-Cutting Themes** | Component 5:<br>"When":<br>Workflow | Phase 5:<br>Prototype | **Stage 2: Translating Research Findings into App Features** | | | Phase 4:<br>Post-Market Surveillance |
| Theme 1:<br>Target Population Involvement | | Phase 6:<br>Gather | Step 5:<br>Select User Preferences | | | |
| Theme 2:<br>Theoretical Basis | | Phase 7:<br>Build | Step 6:<br>Select Intervention Functions | | | |
| Theme 3:<br>Implementation Focus | | **Stage 3: Assess** | Step 7:<br>Select BCTs | | | |
| | | Phase 8:<br>Pilot | Step 8:<br>Translate BCTs into App Features | | | |
| | | Phase 9:<br>Evaluate | **Stage 3: Pre-Testing and Refinement** | | | |
| | | **Stage 4: Share** | Step 9:<br>Piloting Potential App Features with Users and Experts | | | |
| | | Phase 10:<br>Share | Step 10:<br>Refining App Features and Generating Content | | | |

### *Step 1*

A comparative review and analysis of the seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category reveals only two approaches, specifically Approaches #8 and #12, to explicitly discuss steps and activities concerning the formation and formalisation of a multi- and interdisciplinary team at the preliminary outset of the digital health intervention development process. Approach #8 emphasises the importance of "engag[ing] a multi- and interdisciplinary team" at the start of a project (Mummah, et al., 2016, p.5). Approach #8 underscores that the digital health intervention arena is becoming "increasingly acknowledged [as] an inherently transdisciplinary endeavour" that requires involvements and (knowledge and expertise) contributions from a range of heterogeneous specialists and actors, including user centred designers, health behavioural intervention researchers, and industry partners, to name a few. Given the multi-dimensional and multi-

faceted complexity of the digital health intervention arena, Approach #8 strongly argues that "only a true multi- and interdisciplinary team will have the knowledge and expertise to address these complex factors in tandem" (Mummah, et al., 2016, p.5). Furthermore, Approach #8 recommends that all multi- and interdisciplinary team members actively engage and participate throughout the whole digital health intervention process, which in turn helps the team proceed through each stage of the process in a nimble, cooperative and collaborative manner, and fosters greater buy-in at all stages. Active engagement and participation throughout also helps ensure that all team members are on the same page when it comes to understanding the health problem, the targeted health behaviour, the needs and preferences of the target population group, and the theoretical underpinnings of the digital health intervention. Moreover, Approach #8 highlights that enlisting a multi- and interdisciplinary team fosters and facilitates the generation of more creative and divergent ideas and digital prototypes, which has been evidenced to lead to more innovative designs, and more effective and efficacious final digital health intervention products (van Velsen, Wentzel and van Gemert-Pijnen, 2013; Fico, 2015; Chokshi and Mann, 2018) and mHealth behaviour change apps specifically (Mercer, et al., 2015; Edwards, et al., 2018; Munro, 2018).

Similar to Approach #8, Approach #12 also stresses the importance of assembling and establishing a multi- and interdisciplinary team from the onset of the agile mHealth app development process, defined in Phase 0, the "Project Identification" stage. Once a multi- and interdisciplinary team is formed, Approach #12 identifies a few other activities which it recommends performing in Phase 0, which includes: defining the project vision; stipulating the product vision (that is, the vision of the specific mHealth app); formalising initial project requirements; establishing team requirements; creating partnership engagements (with other stakeholders and third-party members); acquiring and finalising project funding and resources; and conducting a relevant and applicable market analysis. In addition to these team and project related activities, Approach #6 briefly touches on the multi- and interdisciplinary team of "experts" working together during the first "Conceptualisation" stage to create a process plan for the design, development and evaluation of a given mHealth behavioural change intervention app. Notably though, Approach #6 makes no other mention of the importance of this team formation, nor discusses activities pertinent to a collaborating multi- and interdisciplinary team. In sharp contrast to the detailed discussions in Approaches #8 and #12, and in comparison to the minimal mention in Approach #6, Approaches #7, #9, #10 and #11 do not explicitly discuss steps or activities pertaining to the establishment and formalisation of a multi- and

interdisciplinary team prior to commencing the digital health intervention development process. Overall, in essence, the digital health intervention process, and particularly the mHealth behaviour change app intervention process, is "multi- and interdisciplinary by necessity" (Mercer, et al., 2015, p.2), and project preliminary thoughtful consideration of its formation and formulation is imperative for carrying out a successful project.

Once a multi- and interdisciplinary team has been established and formalised, a comparative overview of the seven information systems and technology multi- and interdisciplinary approaches reveals two main ways in which *Step 1* can initiate the digital health intervention development process. On the one hand, as a first option, *Step 1* can begin by formulating a conceptualisation of the health problem, together with a conception of the intervention project or the health behavioural change intervention in particular. On the other hand, as a second option, *Step 1* can begin by conducting qualitative research with the intended target population group, which in turn informs the conceptualisation of the health problem, together with the intervention project or the specific health behavioural change intervention. Approaches #6, #7, #9, #11 and #12 adopt the first option, whereas Approach #8 adopts the second option. Approach #10 adopts neither the first or second option, and instead fails to conceptualise or formulate the health problem, project and intervention from the onset altogether. Notably though, Stage 1 in Approach #9 and Phase 0 in Approach #12 first begin by conceptualising the health behavioural change intervention, yet later in Stage 1 and Phase 0, respectively, both approaches suggest performing qualitative research with user representatives of the target population. Approaches #9 and #12 therefore demonstrate a form of amalgamation of both the first and second options.

Looking at the first option, *Step 1* begins with conceptualisation by seeking to understand the problem space and target population group. Stage 1 (Understanding the Problem and User Preferences) in Approach #9 provides four steps to achieve this. For this analysis, these steps will be referred to as activities under *Step 1*, including namely: *Activity 1.1* (define the problem and the target population group); *Activity 1.2* (select the target behaviour); *Activity 1.3* (specify the target behaviour); and *Activity 1.4* (understand the target behaviour and user preferences) which comprises *Activity 1.4.1* (understand the target behaviour) and *Activity 1.4.2* (understand user preferences for technological components). Stage 1 (Conceptualisation) in Approach #11 shares activities with Approach #9, specifically: Sub-Stage 1.1 (define the health behavioural problem, context and target audience) which corresponds to Activity 1.1; Sub-Stage 1.2 (select

target behaviour(s)) which matches with Activity 1.2; and Sub-Stage 1.3 (specify the target behaviour(s)) which is equivalent to Activity 1.3. In comparing these initial activities in *Step 1*, some activity guidelines can be outlined for intervention designers and developers.

*Activity 1.1* aims to define the health problem in behavioural terms (for example, insufficient physical activity). Approach #11 refers to the Behaviour Change Wheel (BCW) to guide this first activity. In *Activity 1.1*, Approach #11 suggests creating a health behavioural problem statement, which concisely describes the problem and its associated context and target population group. Approach #11 also recommends creating a three-row and two-column table (Smith, et al., 2016, p.532) to help define the problem in behavioural terms, with "what behaviour?", "where does the behaviour occur?", and "who is involved in performing the behaviour?" written in the left column, and the answers written in the right column. Approach #9 suggests reviewing literature and empirical study findings to define the health problem in behavioural terms and its associated context and target population group. Additionally, Approach #9 suggests using the socioecological model (initially presented and discussed in Chapter 3) to create a diagram that nests the target audience in the centre, therefore adopting a consumer- or individual-centred perspective.

*Activity 1.2* aims to select the target behaviour (for example, reducing physical inactivity by increasing walking). Approach #11 refers to the BCW to guide this second activity. In *Activity 1.2*, Approach #9 and #11 specify writing a list of possible target behaviours that can potentially be selected to facilitate changing the health behavioural problem (defined in Activity 1.1). From the list, one or two specific target behaviours are selected. Approach #9 suggests conducting focus groups and holding discussion sessions with experts or health behavioural specialist consultants (such as specialists in sport, exercise and physical activity) to ascertain the optimum behaviour(s) to target. Approach #6 similarly urges for expert focus groups, but also recommends reviewing findings from relevant literature and empirical studies, as well as holding brainstorming sessions with the multi- and interdisciplinary team members.

*Activity 1.3* aims to specify the target behaviour, in which a highly specific target behaviour is selected. Approach #11 refers to the BCW to guide this third activity. According to Approaches #8, #9 and #11, this target behaviour essentially defines both the purpose of the health behavioural change intervention and the outcomes by which the intervention will be assessed. To translate a selected target behaviour (from Activity 1.2) into a highly specific target behaviour, more particularised details are required. For example, an initially selected broader

target behaviour may be ‘to reduce physical inactivity by increasing walking’; yet a more refined and specific target behaviour may be ‘to reduce physical inactivity by walking 10 000 steps each day’. Approach #8 suggests that when specifying the target behaviour, intervention designers and developers need to ensure that the specified target behaviour directly serves to meet the health behavioural outcome, and aligns with the broad intervention goal. Approach #9 also emphasises carefully specifying the context in which the specified target behaviour occurs. Moreover, Approach #8 provides five principles to help guide the selection of a specified target health behaviour, including: a behaviour that is familiar and well-accepted by the target population; an evidence base that demonstrates a significant benefit associated with changing the target behaviour; a target behaviour that is highly specific and countable, and hence more actionable; a target behaviour that is framed positively or negatively (to increase or decrease something); and optimally a target behaviour that if change demonstrates potential for producing cascading beneficial effects on other related and reinforcing health behaviours. Additionally, to further support intervention designers and developers in Activity 1.3, Approach #9 and #11 recommend creating a target behaviour specification statement, and Approach #9 further suggests creating a target behaviour specification table. The table outlines concise details pertaining to the specified target health behaviour, starting with a succinct statement of the target behaviour, followed by seven questions, asking: “who needs to perform the behaviour?”; “what do they (the who) need to do differently to achieve the desired change?”; “when do they need to do it?”; “where do they need to do it?”; “how often do they need to do it?”; “with whom do they need to do it?”; and “in what context do they need to do it?”. An example of this table is provided in Approach #9 (Curtis, Lahiri and Brown, 2015, p.8).

Once the target behaviour has been specified (in *Activity 1.3*), *Activity 1.4* aims to understand the target behaviour and users’ preferences by conducting qualitative empirical research studies with representative target (end user) participants. A valuable contribution made by Approach #9 is that is specifies conducting qualitative research in *Activity 1.4* by exploring from both the health behavioural science perspective (using theoretical frameworks such as the COM-B Model and TDF) as well as the mHealth app perspective (harnessing information systems methods such as UCD). According to Approach #9, the former perspective explores understanding the facilitators and barriers for a specified target behaviour, and the latter perspective explores understanding users’ preferences of app design features and interface elements. From the formerly mentioned perspective, *Activity 1.4.1* uses qualitative empirical

studies (namely focus groups) with users to better understand the target behaviour and to inform the creation of a COM-B Behavioural Diagnosis table. The COM-B Model is a validated framework at the centre of the BCW, which defines health behaviour as part of an interacting "behaviour system" where "capability" (C) [psychological and/or physical capabilities], "opportunity" (O) [physical and/or social opportunities] and "motivation" (M) [reflective and/or automatic motivators] all need to be present to enable "behaviour" (B) (Michie, van Stralen and West, 2011, p.4). The Theoretical Domains Framework (TDF) provides a validated set of fourteen behaviour change domains which is useful for identifying facilitators and barriers that influence behaviour change in knowledge translation and implementation applications (Michie, et al., 2005; Cane, O'Connor and Michie, 2012). Based on these two theoretical frameworks, intervention designers and developers can conduct qualitative studies (focus groups) that discuss COM-B and TDF relevant topics, particularised to the specified target health behaviour. The findings from these focus group sessions are used to create a list of COM-B and TDF related topics. This list of topics then informs the creation of a COM-B Behavioural Diagnosis table which outlines columns covering each COM-B category, along with its associated theoretical domain(s), themes and sub-themes, and relevant example quotes from focus group participants. A thorough example of a COM-B Behavioural Diagnosis table applicable to the mHealth behaviour change intervention app context is provided in the supplementary material of Approach #9 (Curtis, Lahiri and Brown, 2015, p.15, Multimedia Appendix 1). Similar to Approach #9, Approach #11 also (explicitly) discusses using the COM-B Model, and (latently) discusses creating a COM-B Behavioural Diagnosis table. However, a marked distinct between the two approaches is that Approach #9 develops the diagnosis table based on qualitative research findings (with target user representatives), whereas Approach #11 performs a diagnosis based on findings from existing literature and published (secondary) empirical studies. From the latter mentioned perspective, *Activity 1.4.2* uses qualitative empirical studies with participants to better understand users' preferences for technological components, and to inform the creation of an App Feature Preference table. To create the App Feature Preference table, focus groups are conducted and a series of semi-structured questions are asked with the intention of identifying and extracting themes and subthemes of users' preferences, and relevant associated example quotes from focus group participants. An example excerpt of an App Feature Preference table is provided in Approach #9, with some themes including aesthetics, gamification and time saving (Curtis, Lahiri and Brown, 2015, p.8). User participants can also be asked which commercial smartphone and mobile operating systems they prefer, such as Android, Apple, Windows and Blackberry.

Thus far, *Activities 1.1*, *1.2*, *1.3* and *1.4* have looked at the first option in *Step 1*, which begins with conceptualisation by seeking to understand the problem space and the target population group. Alternatively, in looking at the second option in *Step 1*, Approach #8 proposes first conducting qualitative research studies prior to selecting and specifying the target health behaviour. In comparison to the first option, this second option essentially reverses Activity 1.4 with Activities 1.2 and 1.3, and (a broader, vague form of) Activity 1.1 immediately precedes and informs the qualitative studies. According to #8, Phase 1 [nested as the first step in Stage 1 (Integrate)] should first aim to "empathise with target users". Phase 2 [also nested in Stage 1] then subsequently aims to "specify the target behaviour" based on the findings from the qualitative studies. The value in taking this target user-empathetic approach is that, from the initial onset, it seeks to gain an in-depth understanding of users' needs and goals. In addition, according to Approach #8, it also aims to move beyond what target users might be able to explicitly articulate, and seeks to uncover and extract any unmet or latent user needs, values and motivations that can help inspire more innovative and create mHealth intervention app solutions. In critically comparing the first and second possible option, both have strengths and weaknesses. For example, performing qualitative research from the get-go may require significantly more resources and time before specific target behaviour(s) can be clearly defined, whereas it can also open opportunities for identifying latent and undiscovered user needs and goals. On the contrary, defining the health problem, and selecting and specifying the target health behaviour prior to performing qualitative studies can significantly save time and resources. Furthermore, defining the area of focus beforehand can be considerably helpful for multi- and interdisciplinary team members in terms of having a better idea as to what questions to ask users when it comes to conducting qualitative studies (later in Activity 1.4). Moreover, since identifying and defining the target population group is part of Activity 1.2, aiming to conduct qualitative research with 'supposed' target users from the onset may be more challenging, particularly since the characteristics and parameters of the targeted group are not yet clearly defined. Overall, whether qualitative research is conducted as the fourth activity in Step 1 (like Approach #9; option one) or as the first activity in Step 1 (like Approach #9; option two), either option can be valuable. Although, notably, the positives of the first option seem to outweigh the second option, and what is more is that given the rapidly changing nature of the mobile and smartphone app environment, a multi- and interdisciplinary approach that aims to save time and resources is comparably more feasible, suitable and pragmatically sensible.

Of additional relevance to *Step 1* and *Activities 1.1*, *1.2*, *1.3* and *1.4*, the first phase of Approach #7 focuses on creating a "Conceptual Framework" on a "Theoretical Level", where Component 1 seeks to specify the "why" of the intervention; that is, the "intervention aims" of a particular health behavioural intervention technology project. The intervention aims reflect the intention(s) of the intervention designers and developers. Approach #7 proposes a valuable contribution in that it breaks down "intervention aims" into (1) "clinical aims" and (2) "usage aims". On the one hand, clinical aims are important because they focus on the effectiveness of a health behavioural change intervention, and essentially aim to assess changes in health behavioural outcomes. For example, clinical aims seek to measure changes in determinants (such as knowledge, self-efficacy, perceived skills and intrinsic motivation) and the effects of these changes in increasing physical activity behaviour. On the other hand, usage aims are imperative to clarify because they focus on the technological or digital tool (or platform) through which the health behavioural change intervention is delivered to users. Usage aims essentially aim to assess users' engagement(s) with technological elements (that is, specific digital design features) and the technological platform as a whole. Examples of usage measures include usability, user experience, adoption, usefulness, satisfaction, and overall duration and frequency of app usage. In critically comparing Approach #7 to the other six mutli-disciplinary approaches in the Information Systems and Technological Perspective category, Approach #7 is the only approach that specifies a distinction between clinical and usage aims, and suggests these aims be clearly articulated from the initial onset of a technology-based health intervention project.

### *Step 2*

In moving from *Step 1* to *Step 2*, a comparative overview of the seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category reveals a variety of activities. The diversity of activities in *Step 2* activities arises from differences in the activities performed across the approaches in *Step 1*. To elaborate, as touched on earlier, Approaches #6 and #11 both define their first step as "Conceptualisation" (which includes specifying a target behaviour), followed by their shared second step "Formative Research". Dissimilarly, Approaches #9 and #12 both amalgamate conceptualisation and formative research into their first step. Although, in both approaches, conceptualisation precedes and informs qualitative user research studies (which is performed later in both of their first steps). In contrast to Approaches #6, #9, #11 and #12, Approach #8, as already mentioned,

specifies their first step as “Empathise” (which is essentially formative qualitative research), followed by a second step “Specify Target Behaviour”. Nevertheless, when comparing these five approaches on a higher level of abstraction, regardless of the two different sequential orderings of steps one and two, all five ultimately share activities that fundamentally aim to understand the behaviour and the target population group, and aim to perform formative qualitative user research. With regard to Approach #6, the purpose of Step 2 (Formative Research) is to conduct research with representative users of the target population group. This formative research aims to determine: the target group’s smartphone usage behaviour; the contextual factors that affect their smartphone interactions and usage; the contextual factors that influence their usage of interventions delivered through smartphone apps; and the target group’s user preferences for intervention change methods and techniques. These formative research activities in Approach #6’s Step 2 thus pertain to the technological platform(s) through which a given health behavioural change intervention is delivered, namely smartphone devices and smartphone apps in particular. The findings of this formative research essentially corresponds to the “usage aims” specified in Approach #7’s Step 1. In comparison to Approach #6’s “Formative Research” (Step 2), Approach #11’s “Formative Research” (Stage 2) is somewhat broader, and focuses not only on researching users’ smartphone usage and preferences, but also focuses on gathering user feedback on low- and high-fidelity app prototypes. In contrast to Approach #11, however, other approaches (namely Approaches #6, #8, #9 and #12) tend to focus on prototype user feedback at a later stage of the digital health intervention development process, and not at such an early stage as is seen in Approach #11.

### *Step 3*

Following activities concerning defining and specifying the target behaviour and target population group, and conducting formative qualitative user research on smartphone device and smartphone app usage behaviour and users’ preferences, a transition is made to *Step 3*. *Step 3* can be described as initiating and creating a theoretical and conceptual design for the digital health behavioural change intervention by reviewing, identifying and selecting appropriate theory- and evidence-based intervention strategies (also referred to as components and BCTs). Approach #7 defines Component 2 (of the “Conceptual Framework” on a “Theoretical Level”) in its process as aiming to define the “how” of an intervention; that is, the “behavioural intervention strategies” of a particular health behavioural intervention technology project. According to Approach #7, behavioural intervention strategies are the methods that

theoretically and conceptually determine how intervention (clinical and usage) aims are achieved. With regard to Approach #8, Phase 3 (in Stage 1 "Integrate") in its process aims to "ground" the digital health behavioural intervention "in behavioural theory". In Approach #8, Phase 3 seeks to review and identify "theory-driven behavioural strategies" that are suited to the specified target behaviour, the target population group, and the selected mode or platform of intervention delivery (such as smartphone apps). During these stages, both Approaches #7 and #8 emphasise that the identified and selected behavioural intervention strategies be grounded in, or informed by, validated behavioural theories and models. In comparison to the multi- and interdisciplinary approaches in the Health Sciences Perspective category, Approaches #7 and #8's mentioning of "behavioural intervention strategies" and "theory-driven behavioural strategies", respectively, are synonymous with the health sciences approaches' references to "theory-based methods", "change mechanisms" and "behaviour change techniques" (BCTs). Moreover, similarly to some of the health sciences approaches, such as Approach #5, Approaches #7 and #8 suggest utilising theory- and evidence-based coding taxonomies including the CALO-RE Taxonomy and BCTT v1. In addition to these two taxonomies, Approach #8 proposes the IDEAS "Toolkit of Behavioural Strategies" which uses process motivation theory to guide intervention component design. Examples of behavioural strategies from Approach #8's toolkit include competence, growth mindset, curiosity, reframing, identity, choice/control, pride, taste, competition, and personalisation. Many of these strategies overlap with techniques provided in the two coding taxonomies.

Notably, when reviewing, identifying and selecting suitable BCTs (behavioural intervention strategies) in *Step 3*, Approach #8 stresses that all multi- and interdisciplinary team members be actively engaged and participate in the theory-driven insights process. Multi- and interdisciplinary involvement at this stage can be valuable when exploring, discussing, comparing and reconciling various heterogeneous theoretical and intervention technique insights and perspectives. Furthermore, Approach #7 recommends that team members provide clear rationale when identifying and selecting BCTs deemed suitable for a given digital health behavioural intervention. In comparing Approaches #7 and #8 to Approach #11, reviewing, identifying and selecting BCTs (intervention strategies) occurs in Stage 1 (Conceptualisation), particularly in Sub-Stage 2 (identify intervention options) and Sub-Stage 3 (identify content and implementation options). Approach #11 also suggests employing the two coding taxonomies (CALO-RE and BCTT v1), but additionally proposes a consideration of the BCW and the TDF. Furthermore, in terms of the BCW and the TDF, Approach #9 aims to identify

and select intervention functions and BCTs which corresponds to Step 6 (select intervention functions) and Step 7 (select BCTs) in its process, respectively. In Step 6, Approach #9 suggests using the COM-B Behavioural Diagnosis table (output from *Step 1*, *Activity 1.4*), together with the BCW and the TDF, to guide the selection of intervention functions that are likely to bring about health behavioural changes. Based on these theoretical frameworks and models, Approach #9 recommends creating a Theory and Intervention Function Component Map (table) which outlines: the COM-B category; the theoretical domains (from the TDF); sub-themes of each theoretical domain; intervention functions; and examples of how the intervention functions can be applied in terms of the project context. An example excerpt of a Theory and Intervention Function Component Map (table) is provided in Approach #9 (Curtis, Lahiri and Brown, 2015, p.9). Step 7 in Approach #9 then takes the selected intervention functions, and reviews, identifies and selects suitable BCTs that map to each intervention function. To identify and select suitable BCTs, Approach #9 suggests reviewing relevant literature and findings from empirical studies to help inform the identification and selection of the 'most promising' evidence-based BCTs, particularly in relation to the target behaviour, target population and contexts-of-use. The selected BCTs (in Step 7) need to link to the selected intervention functions (from Step 6). Approach #9 therefore recommends extending the Theory and Intervention Function Component Map (table) by adding in the selected BCTs in the far right column, thus creating a Theory-Intervention Function-BCT Map (table). The Theory-Intervention Function-BCT Map (table) outlines: the COM-B category; the theoretical domains (from the TDF); the associated intervention functions (based on the BCW); and the selected BCTs linked to each intervention function. Furthermore, Approach #9 suggests consulting with health psychologists (as knowledge experts) to review and verify the Function-BCT Map. An example table of a Theory-Intervention Function-BCT Map is provided in Approach #9 (Curtis, Lahiri and Brown, 2015, p.10). Both tables discussed by Approach #9 can be valuable for supporting multi- and interdisciplinary communication and collaborative team work. Important to point out is that although these tables are discussed under Steps 6 and 7 in Approach #9, they fall under *Step 3* in this critical comparative discussion on information systems and technology approaches.

On an additional note, as discussed above in *Activity 1.4*, Approach #9 not only recognises the health behavioural science perspective (which adopts the BCW, the COM-B Model and the TDF) in *Activity 1.4.1*, but also recognises the mHealth app perspective (which adopts information systems methods such as UCD) in *Activity 1.4.2*. The valuable contribution

proposed in relation to the latter perspective is Step 5 in Approach #9's process, which aims to select users' preferences based on the qualitative findings from user research conducted in Step 4.2. In Approach #9's Step 5 (Select User Preferences), intervention designers and developers can conduct qualitative studies (such as focus groups) with user representatives to ascertain whether users "accept" or "reject" various preference options. Based on the user preference feedback from participants in the focus group sessions, intervention designers and developers can create a table that outlines: user preference themes (such as app features, usability, aesthetics); specific user preference feature statements that link to each theme; whether users generally "accept" or "reject" each preference feature; and reasons that guided their acceptance/rejection decision. However, in the event that intervention designers and developers are unable to conduct primary qualitative studies with user representative participants, they can refer to literature and empirical studies that have similar foci in terms of target behaviour, target population and digital platform. An example excerpt of users' decisions regarding their acceptance or rejection of various user preferences is provided in Approach #9 (Curtis, Lahiri and Brown, 2015, p.9). Important to point out again, as like above, is that the table discussed under Step 5 in Approach #9 falls under *Step 3* in this critical comparative discussion on information systems and technology approaches. Another point to highlight here is that with this user preference table, Approach #9 offers valuable insight into users' likes and dislikes particularly with regard to the selected platform of intervention delivery, namely the features pertaining to mHealth smartphone apps. Moreover, in keeping with the discussion on the selected technological platform of intervention delivery, a critical comparison of the seven information systems and technology approaches reveals Approach #11 as exhibiting a limitation in that it only considers the digital platform (or mode) of intervention delivery in Sub-Stage 3 of its process. The other approaches, in comparison, consider the characteristics and functionalities of a selected digital platform (such as smartphone apps) earlier on in the digital health intervention development process.

Overall, in short, *Step 3* aims to review, identify and select behavioural change techniques (BCTs) that are evidenced as suitable for the specified target health behaviour, the defined target population group, and the selected platform of intervention delivery (such as smartphone apps). The selection of BCTs can be informed by literature, findings from published empirical studies, or primary qualitative research (such as focus groups, interviews or online surveys). In addition, *Step 3* aims to determine users' preferences with regard to the selected technological platform of intervention delivery (such as smartphone apps). Similarly to the reviewed and

selected BCTs, users' preferences can be also be informed by reviewing literature, findings from empirical studies, or conducting primary qualitative research studies (such as focus groups).

### *Step 4 and Approaches #6, #8, #9, #10 and #11*

Moving from *Step 3* to *Step 4*, intervention designers and developers transition from the theoretical and conceptual design of a digital health behavioural change intervention, to a more concrete design. In *Step 4*, the activities constituting this materialisation process towards a more concrete design can be extracted from various steps, stages, phases and components of all seven of the multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category. Language generally differs between the seven approaches when referring to activities relevant to the material idea generation and concrete design of a digital health intervention. Approach #8 refers to *Step 4* as Stage 2 (Design) which comprises four phases: Phase 4 (Ideate); Phase 5 (Prototype); Phase 6 (Gather); and Phase 7 (Build). The nature of Stage 2 is highly iterative and rapidly cyclical. Essentially, the four phases function in a quick cycle that allows for the iterative ideation, refinement and improvement of ideas regarding the design of the concrete digital health intervention. The formation of the iterative design cycles, however, is neither fixed nor rigid, and can be subject to team members' discretion given the nature of the project at hand. For instance, it is likely that Phases 4, 5 and 6 be adopted together when performing fluid and rapid idea generation and design solution cycles, whereas Phases 6 and 7 are likely to be adopted together to rapidly design, test and refine a minimum viable product (MVP). Nevertheless, all iterative design cycles will operate to continuously take into account multi- and interdisciplinary team members' input, relevant behavioural theory and users' feedback; all in relation to the target behaviour, population and technological platform. Phase 4 (Ideate) in Approach #8 contributes to *Step 4* because it aims to conduct brainstorming idea generation sessions as a means to ideate creative and innovative implementation strategies and design solutions relevant to the foci of interest in the project. Approach #8 recommends that multi- and interdisciplinary teams employ divergent thinking techniques and various design artefacts to facilitate the joint idea-generating sessions, and that it is important for heterogeneous team members to practice deferred judgement when generating inter-disciplinary creative ideas and design solutions. Phase 5 (Prototype) in Approach #8 provides a contribution to *Step 4* in that it aims to iteratively create, refine and improve low-fidelity potential prototype products. These prototypes function as design boundary objects (design

artefacts) in supporting and facilitating multi- and interdisciplinary team discussions, and serve as design artefacts for bridging and assisting transitions between rapid iteration cycles. Depending on the particulars of the digital health intervention project and team dynamics, various prototyping techniques can be employed to guide the prototyping process, such as parallel prototyping or sequential prototyping. Notably, Approach #8 emphasises that prototypes be created and shared from early on in the design stage, in order to enrich the collaborative creative idea generation, refinement and co-production process as much as possible. In *Step 4*, prototypes can be developed in various forms, although at this stage, low-fidelity, time-saving, low-resource and low-cost forms are recommended, such as design feature mock-ups, user interface screen mock-ups, storyboards, thumbnail sketches and wireframes.

Phase 6 (Gather) in Approach #8 contributes to *Step 4* in that it aims to test and gather user feedback from representatives of the target population group (acting as participants) concerning the design ideas and design solutions. The main intention behind this stage is to uncover, elicit and gather users' impressions, interests, feedback, concerns and suggestions in response to the prototype or prototypes presented to them. This feedback should aim to consider both the health sciences and the information systems perspectives (as discussed in Approach #9 above). From a health sciences perspective, this means gathering user feedback on the prototype's (or prototypes') behaviour change techniques (intervention strategies) or the health behavioural change intervention as a whole. From an information systems perspective, this entails gathering user feedback on the prototype's (or prototypes') usability, user interface design, user experience design, persuasiveness, engagement, language, aesthetics, and the ways in which BCTs are translated or operationalised into digital design features. To gather user feedback from either perspective, Approach #8 mentions a variety of methods that can be employed, including information conversations, (online or paper-based) surveys, focus groups, usability tests, cognitive walkthroughs, think-aloud tests, user experience design tests, semi-structured interviews, or in-depth qualitative interviews. In essence, the main goal of this prototyping stage is to increasingly inform concrete design refinement and focus. Given this goal, Phase 6 is generally performed with Phases 4 and 5, or with Phase 7. Phase 7 (Build) in Approach #8 contributes to *Step 4* in that it aims to develop a functional minimum viable product (MVP). According to Approach #8, the core tenant of this MVP build process is "to avoid wasting precious time and resources on perfecting a product" (Mummah, et al., 2016, p.4). The goal of Phase 7 should instead be directed at quickly developing a minimum version of the product,

without incorporating additional unnecessary features; which will provide sufficient facilitation for pilot testing with users in the subsequent Phase 8. An MVP is essentially an alpha version of the final digital health behavioural change intervention product (May, 2012). Aspects considered for incorporation in an MVP for the mHealth app context include decisions regarding: user experience; visual and user interface design; content; logical flow; trigger push notifications; graphs and summary report calculations; analytics (based on dataset captures of usage); and metadata analytics (such as just-in-time adaptive interventions and real-time data collection and tailoring). Moreover, as a MVP alpha version, an mHealth app should allow for testing of the primary intervention components (strategies or BCTs), the core design features and the main visual elements, as well as the key content delivery systems. Approach #8, however, underscores a key challenge of Phase 7, which refers to the practical weighing and balancing of different demands and priorities held by participating heterogeneous team members. For instance, balancing the influence of behavioural theory, user needs, technical elements, design features, and the operationalisation of intervention techniques; all against technical, financial, human capital, practical and time feasibility considerations and constraints. Furthermore, Approach #8 cautions that intervention designers and developers be cognisant of the commonly held false assumption that the more BCTs are incorporated, the more likely an intervention is to be effective. Fundamentally, the iterative process of building, testing and refining prototypes and an MVP alpha version in preparation for piloting is a crucially integral stage of the digital health intervention development process.

Further inputs into *Step 4* are offered by Approaches #9 and #10. Approach #9 specifically specifies Step 8 (in Stage 2) as principally dedicated to translating BCTs into mHealth app design features. Based on the App Feature Preference table and the Theory-Intervention Function-BCT Map (table) discussed above in Steps 1 and 3, respectively, Approach #9 aims to translate and operationalise the BCTs (selected in Step 3) into material app design features. A valuable contribution offered to *Step 4* by both Approaches #9 and #10 is the additional integration of gamification elements and principles (such as achievement badges and trophies). Approach #9 suggests creating a BCT-Gamification list as well as a BCT-UCD App Translation Map (table), which outlines the linkages between selected BCTs, gamification techniques/principles, and mHealth app design features. In addition to gamification, Approach #9 proposes another valuable contribution in recommending that intervention designers and developer consult and liaise with consultants from commercial app companies, particularly when determining how BCTs can be translated and operationalised into persuasive and

meaningful app design features. Moreover, Approach #9 recommends consulting and liaising with software engineering consultants to develop sequenced UML Modelling diagrams on both the user journey, and the intervention delivery flow (which illustrates where and how an intervention's BCTs and gamification principles are linked to specific app design features). In relating back to the phases defined by Approach #8, these mentioned contributions offered by Approach #9 can further enrich the iterative and rapid cyclical design-test-refine prototyping and MVP alpha process. Further analysis of Approach #9, however, also reveals Step 10 "Refining App Features, Generating Content and Developing the App Prototype" as offering some contributions to the design-test-refine prototyping cycle. Approach #9's Step 10 essentially aims to integrate and translate theoretical and user design specifications into an mHealth intervention app's design and delivery features. In this step, content is also generated – for instance, content for messages, message framing (gain versus loss), notifications, quiz questions, tips, hints and motivation messages. A Content Specification table can be created for easy referral. An example excerpt of a App Content Specification table is provided in Approach #9 (Curtis, Lahiri and Brown, 2015, p.13). In Step 10, as mentioned in Step 8, Approach #9 recommends creating detailed user journey flows that can illustrate the features and functionalities of an mHealth app. Additionally, Step 10 discusses developing an mHealth intervention app prototype based on all the design-related activities performed under its process's Stage 3 (Pre-Testing and Refinement). Important to note though, and considered a fault by the researcher conducting this critical analysis, is that these design-related activities in Approach #9's Step 10 fall subsequent to what is defined as a "Piloting" stage. Pilot testing, by definition, generally occurs subsequent to pre-testing and refinement. With this in mind, although Approach #9 offers several valuable contributions to *Step 4*, it has also problematically blends pre-testing, refinement, prototyping and pilot testing activities together, thus muddying the waters and potentially resulting in ambiguity and discombobulation for involved multi- and interdisciplinary team members.

On another note, Approach #10 provides a novel contribution to the multi- and inter-disciplinary knowledge base with its dyadic lenses for the design of smartphone-based mHealth behaviour change intervention apps. Approach #10's dyadic lenses essentially provide intervention designers and developers (from both the health sciences and the information systems perspectives) with means to bridge behavioural theory and BCTs into operationalised app design features. The dyadic lenses offer cross-links between theoretical frameworks and technological design instantiation, and its supplemented by descriptions, guiding questions,

practical examples, illustrative explanations and graphical screenshot (user interface design) examples of real-world mHealth apps. Additionally, Approach #10's dyadic lenses are valuable in that they integrate principles of persuasive systems design; an important contribution that Approaches #6, #8, #9, #11 and #12 fail to recognise and consider. What is more is that the authors of the dyadic lenses developed and published an online interactive toolkit (via link: https://www.lensesofmotivationaldesign.com/references). When carrying out *Step 4*, intervention designers and developers can freely access and use the online toolkit as a boundary object to support and facilitate their multi- and interdisciplinary collaborative efforts when concretely realising the design of their mHealth intervention app prototype and MVP alpha versions. Details pinpointing dyadic lenses' twelve behavioural theories (from the health sciences perspective) and six categories of twenty-six design features (from the information systems perspective) can be referred to in Table B in Appendix H.

In comparing Approaches #8, #9 and #10 with Approaches #6 and #11, slight differences can be identified. To briefly recap, Approach #8 amalgamates Phases 4 to 7 in their process's Stage 2 (Design), Approach #9's Step 8 (in Stage 2) aims to translate BCTs into app design features and its Step 10 (in Stage 3) aims to refine app features, generate content and develop an mHealth app prototype, and Approach #10's dyadic lenses assist team members in bridging the disciplinary divide. In contrast, Approaches #6 and #11 adopt a seemingly different approach. Approach #6 does not specify a "design" step at all, but instead jumps from "formative research" (in Step 2) to "pre-testing" (in Step 3), therefore revealing a gap and limitation of the approach's process. Although, in critically comparing the approaches, Step 3 in Approach #6 essentially correspond to Stage 2 in Approach #8 (including Phases 4 to 7). Step 3 in Approach #6 is described as aiming to pre-test the proposed mHealth intervention design with representative target user participants as a means to gathering user feedback on a prototype version. Similar to Phase 6 in Approach #8, Step 3 in Approach #6 aims to gather user feedback on the mHealth prototype's intervention content, messages, design features, style, aesthetics, format, regimen and language. Methods mentioned by Approach #6 to perform user feedback testing include focus groups, interviews and online surveys. Step 3 in Approach #6 also follows a design-test-refine cycle, similarly to the four phases in Stage 2 in Approach #8. Comparable with Approach #6, Approach #11 also overlooks a "design" stage, and merges "formative research" together with "pre-testing" in Stage 2. However, upon reviewing Approach #11, the aim of Stage 2 is to translate and refine an mHealth app intervention's conceptualisation (from Stage 1) into a prototype that supports user behaviour, the contexts-of-use, and user

preferences. This illuminates that the main aim of Approach #11's Stage 2 again resembles Approach #6's Step 3 and Approach #8's Stage 2. In terms of methods, Approach #11 recommends using qualitative and quantitative techniques to perform activities concerning the translation of the conceptualised idea, the gathering of user feedback, and the iterative design of a working and functional prototype. These three activities in Stage 2 of Approach #11 again correspond to the four phases in Stage 2 in Approach #8, which incorporates iterative activities of ideating, prototyping, gathering and building an MVP alpha version of an mHealth app. Similar to Approach #8's Phase 6 and Approach #6's Step 3, Approach #11's Stage 2 aims to elicit and gather user feedback concerning user acceptance, user engagement, information needs, user flows and user preferences. Notably though, a distinct contribution offered in Approach #11 – which is not offered in Approaches #6, #8, #9 and #10 – is the suggestion to employ the Health-ITUEM framework and criteria for guiding the mHealth app's assessment during the prototype pre-testing process. The Health-ITUEM, which is short for the Health Information Technology Usability Evaluation Model, provides a set of criteria for evaluating the usability of mHealth app technology specifically (Brown, et al., 2013). The criteria laid out in the Health-ITUEM include: error prevention; completeness; memorability; information needs; flexibility and customisability; learnability; performance speed; and competency (Brown, et al., 2013). Overall, with regard to *Step 4*, an overview of the findings from the critical review and comparison between Approaches #6, #8, #9, #10 and #11 uncovers the existence of many similarities, albeit several differences, between the approaches' steps and activities concerning the concrete design realisation of a digital health behavioural intervention.

### *Step 4 and Approaches #7 and #12*

In addition to the findings revealed from critically comparing Approaches #6, #8, #9, #10 and #11, further similarities, differences and insight contributions can be identified when analysing and comparing Approaches #7 and #12 and their relation to *Step 4*. Approach #7 does not specify an explicit "design" stage for the concrete realisation of design conceptualisation, although it does define a "Technological Framework" on an "Instantiation Level". The "Instantiation Level" comprises three components, namely Component 3 (BIT Elements), Component 4 (Characteristics) and Component 5 (Workflow). Together these components essentially aim to guide intervention designers and developers when translating the theoretical and conceptual digital behavioural intervention into a technical instantiation. At the crux, this key aim mirrors the aims conveyed in the design-related steps and activities of Approaches #6,

#8, #9, #10, #11 and #12. Firstly, Instantiation Component 3 is defined as the "What" stage and focuses on "BIT Elements", which refers to "what" is delivered (through the digital platform). In this stage, intervention designers and developers aim to map the selected BCTs (intervention strategies) into BIT elements. BIT elements reflect "what" is provided to the user. The elements are the distinct objects of a digital health intervention intended to implement the BCTs. They are described in Approach #7 as "the actual technical instantiations" of BCTs present in the digital health intervention, such as the actual technical elements of a mHealth smartphone app. According to Approach #7, commonly used BIT elements applicable to the smartphone app platform include: a "content delivery" or "information delivery" element (one-way content or information provided to the app user); "notifications" (individual messages pushed to the app user); "logs" or "logging" elements (user-entered data collection); "messaging" elements (social support and networking capabilities); "reporting and visualisation" elements (summaries and reflections of data collected by the app that is provided back to the app user). Further details on these examples are provided in Table B in Appendix H. In brief, BIT elements are the aspects of the digital health intervention with which the user actually (directly) interacts.

Secondly, Instantiation Component 4 is defined as the "How (Technical)" stage and focuses on "Characteristics", which refers to "how" the "what" (the elements) are delivered (through the digital platform). Characteristics further refine and define BIT elements across a number of dimensions to better fit the user and to optimise the effectiveness of the BIT elements. Characteristics tend to operate by aiming to improve a user's comprehension, engagement with, and ability to complete tasks. To succinctly compare, BIT elements are considered the "objects", whereas characteristics are the "attributes" of those objects. According to Approach #7, common (although not exhaustive) characteristics applicable to mHealth smartphone apps include: "medium" (the media or format of the element, such as text, audio, video, image); "complexity" (how simplistic or detailed an element is, such as free entry, drop-down menus, barcode scanning); "aesthetics" (the visual attributes of an element, such as colours, sizes, shapes); and "personalisation" (the altering of an element to fit the user's needs, capabilities, demographics, culture, language, personal taste preferences). Notably, Component 4 "How (Technical)" is distinguished from Component 2 "How (Conceptual)", of which was discussed in the early part of *Step 3*.

Thirdly, Instantiation Component 5 is defined as the "When" stage and focuses on "Workflow", which refers to "when" the "what" (the elements) are delivered (through the digital platform). Workflow can be described as the set of rules that determine when and under what conditions each BIT element is delivered to the user over time. Most digital health interventions are designed for repeated interactions over an extended period of time. The workflow determines when specific sets of BIT elements are delivered, the sequence in which they are delivered, and the length of time or duration for which they are delivered. According to Approach #7, common workflows applicable to mHealth smartphone apps include: "user-defined" workflows (there are no predetermined coded rules, so the user decides the timing, sequence and frequency of their interactions with the app's BIT elements); "time-based" workflows (rules define the point of time and passage of time in which BIT elements are made accessible and available (or are released to) the user, such as the provision of new information delivered on a bi-weekly basis); "event-based" workflows (rules define the accessibility or release of BIT elements depending on set criteria detected by the digital health intervention, such as the completion of a task or the detection of a user's state). Just-in-time adaptive interventions (JITAIs) may employ complex workflows that utilise combinations of user characteristics, use data, detected events, and time to determine the delivery of a digital health intervention's strategies or components.

An additional contribution by Approach #7 to *Step 4* is its proposed BIT-Technological Model (the BIT-Tech Model). The BIT-Tech Model is essentially a practical instantiation of the "Conceptual Framework" and the "Technological Framework" together, forming what can be described as a technical implementation plan or a technical prescriptive guideline. The plan is technical in that it can be utilised by system designers and developers to guide the technical development of a digital health intervention. In the context of mHealth apps, a BIT-Tech Model can provide app designers and developers with guidelines regarding the technical development and material realisation of a conceptually designed mHealth behaviour change intervention app. The BIT-Tech Model can be used to show the relationship among software components, the user, and the environment. Given the technical nature of the model, a specific BIT-Tech Model notation has been defined by the authors of Approach #7. The key notations refer to the core constructs of the BIT Model, namely: intervention (I), aim (A), element (E), characteristics (C), workflow (W), data (D), and time (t). Important to note though, is that the authors refer to a specific intervention strategy or component as an "intervention (I)"; whereas this analysis refers to the "intervention" in its entirety, and distinguishes the whole intervention from its comprising intervention strategies. Nevertheless, in respecting the authors' reference, a

supposed “intervention” is thus seen as encompassing a combination of a BIT element and its characteristics; which in technical notation terms is denoted as I=<E, C>. Furthermore, the BIT-Tech Model can be described as composed of several components, namely: a “profiler” (which defines the app user and transmits sensory and user input data to the intervention planner); an “intervention planner” (which is responsible for planning interventions at current time (t) by choosing the relevant intervention elements and respective characteristics); an “intervention repository” (the storage database that stores the intervention elements); and the “user interface” (which delivers the intervention elements to the app user through the app’s design interface). Further details pertaining to the BIT-Tech Model and its practical application (technical instantiation) to a real-world mHealth physical activity app, *MyFitnessPal*, can be referred to in Approach #7 (Mohr, et al., 2014).

Approach #12 contributes to *Step 4* with its Phase 1 “User Experience Design, Development and Alpha Testing” from the “Clinical Development Stage” of its mHealth agile development process. The main aim of Phase 1 is to design and develop several iterations of mHealth app prototypes and alpha versions that increasingly reflect the target users’ needs, values, context, abilities, strengths and limitations or constraints. In comparison to the other six information systems and technology multi- and interdisciplinary approaches, Approach #12 is unique in its employment and use of a software testing technique called Alpha Testing and Beta Testing. Alpha Testing is employed in Phase 1 and will be discussed in this section under *Step 4*, whereas Beta Testing is employed in Phase 2 and will be discussed later under *Step 5*. Alpha Testing is a type of user acceptance testing that is carried out at the intervention designers and developers’ site, which is commonly referred to as in-house testing. Alpha Testing generally uses techniques such as white box testing (testing the internal structures and functional workings of an app), black box testing (testing the functionality and user interface design of an app), and grey box testing (combines white and black box testing; both an app’s functional workings and its functionality) (Naeem, et al., 2015). Approach #8 Phase 1 focuses on utilising user experience design testing and alpha testing techniques to iteratively and rapidly develop many versions of the mHealth app (as a product), and over time, demonstrating gradual design and development improvements and refinements via cyclical feedback loops. Within alpha testing, various MVP prototype versions will be created and iteratively tested with in-house users, under controlled conditions (Naeem, et al., 2015). Prototypes may initially commence as low-fidelity versions (such as sketches, wireframes, screenshots and storyboards) and gradually develop into high-fidelity MVP alpha versions (which are computer- or app-based

interactive and functional representations of the mHealth product). The goal of the iterative and rapid cyclical feedback loops is to continuously create and improve the prototypes and alpha versions in terms of their user interface design (UID) and user experience design (UXD), and to better understand and incorporate the target users' needs, preferences, values, context, abilities, strengths and constraints. Based on users' feedback, the (UI and UX) design improves, features are added/adjusted/removed, and other functionalities are iteratively assessed including privacy, security, risk, barriers, and accessibility standards (such as WCAG 2.0, W3C/WAI). In comparing Approach #12 to Approach #8, reference to alpha versions (in Approach #12) is often interpreted as equivalent to minimum viable products (MVPs) (in Approach #8). The focus of an MVP is to build the core and base functionality and features of an mHealth app, which allows for the key assumptions to be tested with users and feedback can be gathered to inform future MVP version iterations. An MVP is therefore a form of alpha version that focuses on base functionality. As an MVP is improved over time (through several iterations), it develops into a fully functional prototype version of an mHealth app. In comparison to an MVP, a prototype is a broadly inclusive software term referring to any sample, concept, idea or model of an mHealth app. A prototype can range from low-fidelity non-functional versions (and therefore would not be an MVP) to high-fidelity fully functional versions (which would be a late fledged version of an alpha MVP). On this note, according to Approach #12, the goal of Alpha Testing in Phase 1 is to produce an output in the form of a "complete functional prototype" – which in other words is an MVP alpha version – ready for Beta Testing in Phase 2.

Markedly, in order to transition from Phase 1 to Phase 2, Approach #12 lays out several "gating questions". This is another valuable contribution by Approach #12 to *Step 4*. Gating questions can be described as a series of questions that can guide interventions designers and developers in determining whether an mHealth app sufficiently meets certain criteria, before moving to the next Phase of the agile mHealth development process. Examples of gating questions at Phase 1 include: "Is it easy to use?"; "Do people want to use it?"; "Does it perform its intended purpose?"; "Is it safe to use?"; and "Does it align with users' needs, values, preferences, abilities and limitations?". Once these gating questions can be sufficiently answered by intervention designers and developers, and a "complete functional prototype" (MVP alpha version) is ready, the team can transition to Phase 2 for Beta Testing.

### *Step 4 Overview*

In surveying the comprehensive and detailed discussion on *Step 4*, all seven approaches in the Information Systems and Technology Perspective category have offered a variety of insights and valuable contributions to inform and guide the transition from a theoretical and conceptual design from *Step 3* to a materialised concrete design in *Step 4*. Although many similarities, overlaps and differences have been recognised and discussed in critically comparing the relevant "design" activities, steps, stages, phases and components of the seven approaches, the key golden thread focal point has been to translate the theoretical and conceptual design into a material concrete working digital mHealth behavioural change intervention app in the form of an MVP alpha app (high-fidelity functional prototype) that is ready for pilot testing.

### *Step 5: From Alpha Testing to Pilot Testing*

Having designed and produced a high-fidelity MVP alpha prototype by the end of *Step 4*, intervention designers and developers can progress to *Step 5* where the main goal is to pilot test the alpha mHealth app. Pilot testing is a subset of feasibility testing that aims to assess and verify the major components and functionality of a software product, or a software product as a whole. Pilot testing occurs on a small scale, is carried out in preparation for large-scale randomised controlled trials, and is performed before a software product's full deployment and implementation (Eldridge, et al., 2016). Pilot testing is executed under real-time or simulated operating conditions (that is, a specific setting or context) and is carried out with a selected sample group of target population end user representatives (that is, a specific group of users), who participate in trying the software product and provide feedback on it (Lyles, et al., 2017). Feedback from users helps intervention designers and developers debug the software product and tend to any identified weaknesses. In addition, intervention designers and developers can perform pilot testing in preparation for subsequent randomised controlled trials (RCTs). Pilot testing can assist the team in assessing the integrity, reliability and feasibility of a study's design and protocol, can help inform better decisions regarding time, participants and resources, and help team members practice activities they are expected to perform in the large scale RCT studies later on (Eldridge, et al., 2016).

A comparison between the multi- and interdisciplinary approaches reveals four of the seven as defining a clear pilot testing stage in the mHealth intervention development process. Approach #6 defines Step 4 as the "Pilot Study" stage. Approach #8 includes Phase 8 "Pilot Test (for

Efficacy and Usability)" in Stage 3 (Access). Approach #9 includes Step 9 "Piloting Potential App Features" in Stage 3 (Pre-Testing and Refinement). Approach #11 defines Stage 3 for "Pilot Trials". Notably though, in terms of Approach #9's Stage 3, an overt and evident issue is markedly apparent with the wording used to umbrella reference the piloting activities (in Step 9). Approach #9's Stage 3 is uses the words "pre-testing" and "refinement", which are generally used to describe the iterative designing, testing and refining of an mHealth app, and are not generally used to describe pilot testing activities. For example, in contrast to Approach #9, Approach #6's Step 3 "Pre-Testing" and Approach #11's Stage 2 "Pre-Testing Activities" is distinctly preceding and separate to their "Pilot Testing" step and "Pilot Trials" stage, respectively. This reveals a conspicuous distinction between "pre-testing" and "piloting". Therefore, critical thoughts trials and a judgement-making process reveals Approach #9's use of the terms "pre-testing" and "refinement" to be ambiguous and potentially misleading, and as misaligning with the intentions and aims of "pilot testing" procedures. Nevertheless, the pilot testing activities in the four approaches (namely Approaches #6, #8, #9 and #11) exhibit clear similarities and overlaps, regardless of some differences in authors' use of terminology. On the contrary, dissimilar to these four approaches, Approaches #7, #10 and #12 do not recognise, include or discuss a pilot testing stage.

Approach #6 describes its Step 4 "Pilot Study" stage as aiming to test the mHealth intervention's content, regimen and main components with users (participants), with the intention of obtaining any additional detailed feedback that can inform further finalising improvements in preparation for randomised controlled trial testing. Approach #6 also includes additional aims that intend to prepare and assess the processes for subsequent trial testing, including recruitment, registration, data collection and technical considerations. The main intention behind these aims is to resolve as many issues as possible before the main large-scale trial is deployed and implemented. A few example pilot testing questions provided by Approach #6 include asking whether the mHealth intervention is acceptable, whether there are any technical or process issues, and whether the baseline measures are appropriate and informative. In comparing Approach #6 with Approach #8, a few other aims are extricated. Using the minimum viable product (MVP), Approach #8 proposes carrying out pilot testing studies to gather information regarding the acceptability, usability, feasibility and potential efficacy of the mHealth intervention app. The MVP (alpha version) is tested with users to gain further insights into any preferred (or unsatisfactory) features, to pinpoint any problematic or confusing user flows, and to identify any opportunities for improvements to the app's design

features and intervention components. Findings and insights gained from pilot testing studies are used to inform further iterations (versions) of the MVP (alpha version) mHealth intervention app until it is ready for large-scale trial evaluation assessment. Similar to Approach #6, Approach #8 discusses testing and refining the design and implementation procedures in preparation for randomised controlled trial evaluations, suggesting an assessment of recruitment, enrolment, retention and data collection protocols. Approach #8, likewise Approach #6, recommends weeding through as many issues as possible to avoid problems when performing large-scale evaluation effectiveness trials. On another note, Approach #9's Step 9 "Piloting Potential App Features" in Stage 3 fleshes out some further pilot testing pointers. Approach #9 suggests consulting with experts to gain additional insights on the mHealth app's design features and intervention components, and to verify the content of the app. Furthermore, Approach #9 proposes creating pilot testing summary tables and protocol guidelines which can be easily referred to by multi- and interdisciplinary team members.

Similar to Approaches #6, #8 and #9, Approach #11 discusses "Pilot Trials" in its mHealth intervention app development process's Stage 3. In Stage 3, Approach #11 aims to pilot test and finalise the mHealth app intervention prototype in preparation for larger randomised controlled trial evaluation studies. Analogous to the other three approaches, Approach #11 discusses conducting piloting trial studies with target user representatives (participants) over a short-term period, for example, one month. In terms of assessment, Approach #11 also discusses testing the mHealth app with users to gather feedback regarding usage, functionality, preferences, criticisms and suggestions, yet unlike the other approaches have mentioned, also discusses pilot testing users' experiences (which links to user experience design). Additionally, unlike the other three approaches, Approach #11 proposes utilising the Health-ITUEM survey criteria, and suggests having users fill in the survey at the end of the pilot testing period. On another note, resembling Approaches #6, #8 and #9, Approach #11 stipulates ending the pilot testing stage with a fully functional, finalised mHealth app prototype that is ready for long-term randomised controlled trial evaluation testing, thus leading the multi- and interdisciplinary team into the following stage of the process, *Step 6*.

### *Step 5: From Alpha Testing and Pilot Testing to Beta Testing*

However, before progressing to *Step 6*, a noticeable contribution by Approach #12 offers a relevant and valuable consideration which none of the other six information systems and technology approaches recognise or mention. This contribution refers to Approach #12's Phase

2 which is defined as the "Beta Testing" stage of the mHealth agile app development process. Beta testing is a form of "pre-release testing" that aims to gather end user feedback on an app prototype's features and functionality, with regard to its acceptance, content, visual appeal, engagement, usability, utility, privacy and security (Naeem, et al., 2015, p.3; Teo, et al., 2019). Furthermore, the beta testing period aims to uncover and capture any additional issues (such as defects and bugs) that the prior alpha testing period failed to reveal (Naeem, et al., 2015, p.3; Birrell, et al., 2019). Beta testing can also be referred to as user acceptance testing or end-user testing. In comparison to alpha testing and pilot testing, beta testing aims to focus on gathering users' feedback after engaging with and using the high-fidelity mHealth app prototype in real-world conditions; rather than aiming to gain an in-depth understanding of and insight into users' experiences in laboratory or simulated conditions, which is comparably the more predominant focus during alpha testing and pilot testing. Even though the alpha testing process is known to identify and reveal initial issues, findings from empirical studies report beta testing to reveal additional issues based on real-world use-in-context, thus capturing issues that alpha testing fails to identify (Naeem, et al., 2015; Birrell, et al., 2019; Teo, et al., 2019).

Metaphorically speaking, alpha testing and pilot testing is like a dress rehearsal for a theatre production which is not yet open to the public, and where internal on-site and in-house testing is carried out with experts and sampled participants (target representative users) in controlled environments, laboratory settings or specific one-case contexts (for example, on a specific theatre rehearsal stage with a specific group of viewers). In terms of alpha testing and pilot testing, the aim of this dress rehearsal is to assess the components, usability, acceptance and user experience of an mHealth app's features and functionalities. Beta testing, in comparison, is the premier release of the theatre production (on the real-life theatre stage), where only a limited number of public audience members are able to attend and watch the performance for the first time, prior to full public release. In terms of beta testing, the aim of this premier is to make the "beta release" (that is, the beta app prototype version) available to only a limited number of real-world end users, in real time, with the objective of obtaining feedback on the acceptance, adoption, accessibility, quality, robustness, reliability, adherence, privacy and security of the mHealth app (in its beta form) (Approach #12; Naeem, et al., 2015, p.3). Secondary aims of beta testing are to reduce any potential risk of an app's (product's) failure and increase an app's (product's) quality through app end user (consumer) validation (Approach #12; Birrell, et al., 2019).

The use of terminology such as ‘product’ and ‘consumer’ hints at the business perspective that frames the beta testing process. A business perspective is relevant and important to consider since consumer mHealth apps are released via the commercial app industry (and mobile software companies) and are made available to the public (end users) via consumer app markets (such as the Android Google Play and Apple iOS app stores) (Nieborg, 2016). Moreover, many consumer apps, and some mHealth apps in particular, are based on business revenue models that require consumer payment to gain access to “premium” (paid or in-app purchase) app features, which “freemium” (unpaid/free) app versions limit or restrict access (Nieborg, 2016). Examples of a physical activity apps which offer both freemium and premium versions include: *MyFitnessPal*, *Sworkit*, *Nike Training Club*, *Endomondo*, *Strava*, *SWEAT* and *Pokémon Go*, to name just a few. In light of this business perspective, conducting beta testing by circulating “beta release” products to a limited number of real-world end users, in real time, in off-site and real life (uncontrolled) contexts, is unequivocally valuable and essential for improving an app’s quality, for reducing any potential risks, and for fixing or eliminating any identifiable software bugs (Birrell, et al., 2019). Moreover, beta testing is said to afford the multi- and interdisciplinary team a means of getting in touch with their target population (that is, their consumer base in business terms) by allowing them to use the product (app), provide feedback on it, and deliver their perceptions, interpretations and experiences based on real life engagements. Once analysed, this consumer-based information can provide the multi- and interdisciplinary team with valuable insights to further improve the quality of the beta app version by ensuring that its features, functionalities and intervention components align well with target consumers’ (that is, the end users’) needs, preferences and contexts-of-use (Nieborg, 2016).

Given the inherently agile and rapidly changing app software and user preference environments, beta testing provides a suitable approach in that it is reported to take only a few weeks to conduct (Birrell, et al., 2019). Based on end users’ feedback ascertained from the beta testing period (or a series of beta testing cycles), the “beta release” app version is iteratively refined and improved until an updated “beta release” app version is ready for large-scale public release (hence leading to subsequent RCT studies in *Step 6*). Once the iterative beta testing process is complete and the multi- and interdisciplinary team is satisfied with the “beta release” app version, the mHealth app intervention (product) is referred to as a “release candidate” or the “final product” (Naeem, et al., 2015, p.3). To distinguish and elucidate between minor and major changes to app versions over an app’s lifespan (regardless of whether in alpha, beta or

final app product form), semantic numerical sequence-based identifiers are used (Lin, et al., 2014). For example, an app's "beta release" versions can be ascribed numbers 0.9.0, 0.9.1, 0.9.2, which can then transition to "release candidate" or "final product" versions denoted by numbers 1.0.0, 1.0.1, 1.0.2, 1.1.0, 1.1.1, et cetera (Lin, et al., 2014). Once the beta testing period nears an end, in which all of the gathered users' feedback has resulted in iterative fixes and quality improvements to the "beta release" version app prototype, Approach #12 suggests answering a few gating questions before transitioning to the next stage. Examples of gating questions include: "Will people actually use the app?", "Does the app meet the needs of the target user population?", "Can the app be implemented in its intended context?" and "Is there sufficient face validity that the app (product) will address the challenge (health problem) at hand?". According to Approach #12, once the beta testing process is completed and the multi- and interdisciplinary team can affirmatively answer the proposed gating questions, a "successful beta candidate" ("beta release candidate" or "final product") – with no known "show-stopper-class-bug" (Naeem, et al., 2015, p.3) – is made available and ready for large-scale public release, hence leading to *Step 6* in the mHealth app intervention development process in which long-term randomised controlled trial evaluations are performed.

### *Step 6*

Once a fully functional mHealth app prototype "successful beta candidate" has been successfully piloted and beta tested in *Step 5*, the multi- and interdisciplinary team can commence large-scale deployment and implementation of the mHealth app "release candidate" in real-world conditions by transitioning to *Step 6* where focus is given to conducting randomised controlled trials. Often employed as the "gold standard" of evidence in health and medical sciences, randomised controlled trials (RCTs) are usually deemed the most rigorous scientific experimental method for evaluating the effectiveness and efficacy of an intervention (Dick, O'Connor and Heavin, 2017, p.2). Effectiveness and efficacy is stringently determined using hypothesis testing and statistical analysis, where focus is given to examining the causal (cause-effect) relationships between a health intervention and its consequent clinical health outcomes (Kendall, 2003). Given the quantitative nature of RCTs, some common examples of primary outcome measures used for physical activity health behavioural change interventions include: weight loss; body mass index (BMI); body composition; body fat percentage; fat mass; waist-to-hip circumference ratio; and skinfold thickness (Müller, et al., 2016). In the context of smartphone devices, technological capabilities and in-built sensors (such as accelerometers,

gyroscopes and GPS receivers) allow for quantitative measuring and monitoring of users' physical activity engagement levels. By leveraging these capabilities, physical activity apps are often designed to measure objective metrics such as number of steps, intensity of activity, minutes (duration) of activity, frequency of activity, and distance of activity (Jee, 2017; Hardeman, et al. 2019). While RCTs provide an informative means of objectively measuring and assessing health outcome effects, there are a few significant, strong criticisms for their use in the mHealth app context (Kumar, et al., 2013; Jake-Schoffman, Silfee and Waring, 2017; McKay, Slykerman and Dunn, 2019).

One criticism concerns the purely positivistic assumptions upon which traditional RCTs are based; assumptions which are used to inform simple, probabilistic and generalisable statements about the causal relationship(s) between a given mHealth app and its consequent health outcomes (Pham, Wiljer and Cafazzo, 2016). The hallmark of RCTs is to control for contextual variables, and given the inherent complex sociomaterial and sociotechnical nature of mHealth app interventions, purely positivistic experimental designs fail to account for the myriad of confounding variables, the multifaceted array of changing mechanisms and the subtle interlaced nuances between the user, the app and their environmental context (Pham, Wiljer and Cafazzo, 2016). For these reasons, traditional RCTs are criticised for neglecting the complex sociomaterial nature of mHealth physical activity apps, and thus are often argued as incompatible and impractical for properly evaluating mHealth apps' effectiveness and efficacy (Collins, et al., 2005; Mohr, et al., 2015; Jake-Schoffman, Silfee and Waring, 2017; Blandford, et al., 2018; McKay, Slykerman and Dunn, 2019). A second criticism concerns RCTs rigorous methodology which requires an intervention or treatment programme be rigidly "locked down" for the duration of the trial period (Mohr, et al., 2015, p.2). There are two main issues Mohr and colleagues (2015, p.2) identify when "locking down" a technology-based health intervention for purposes of conducting an RCT. The first issue with lock-down relates to the duration of time required to conduct an RCT, and its incompatibility with the mHealth app environment. RCTs are renowned for their notoriously long evaluation timeframe, and have been reported to taking anywhere from a minimum of 2 years (Piantadosi, 2017) to an average of 5.5 years (Pham, Wiljer and Cafazzo, 2016) to perform, and at times, can take up to six or seven years for full publication and dissemination (Jacobs and Graham, 2016). In contrast to these long timeframes, smartphone devices and mHealth apps function in an iterative, agile and rapid-paced environment where the inherent quality of application software and changing user preferences requires continuous evolving, refining and updating over time; therefore,

demonstrating its unsuitability to the long-term, fixed rigidity of the RCT methodology (Pham, Wiljer and Cafazzo, 2016; Jake-Schoffman, Silfee and Waring, 2017). The second issue with locking down a technology-based health intervention in an RCT is that during the trial period, new information and valuable insight is often gained (Mohr, et al., 2015). This new information is often relevant and imperative for improving the quality of the mHealth app intervention in terms of usability, acceptance, engagement, usage and intervention effectiveness. The rigid lock-down model of RCT protocols, however, precludes any possible adjustment to and improvement of the mHealth app intervention during the trial in order to maintain internal validity, and as a consequence, this leads to significant wasted time, effort and resources (Mohr, et al., 2015). This ties to the third criticism, which concerns the intensive time, effort, cost and resource demands considered mandatory for carrying out quality and valid traditional RCTs (Dick, O'Connor and Heavin, 2017). Related issues concern participant recruitment, adherence and retention rates for the large sample sizes deemed fundamental for producing valid empirical RCT results (Pham, Wiljer and Cafazzo, 2016). Additional criticisms and apprehensions have been with respect to potential biases in mHealth behaviour change app intervention RCT research, such as selection bias, information bias, performance bias, detection bias, attrition bias, and selective reporting bias (Han and Lee, 2018). Ethics and strict adherence to ethical protocols are also vitally important for conducting quality reliable, valid and credible RCT studies (Blandford, et al., 2018).

In light of these and other criticisms, new and alternatively adapted evaluation methods have emerged over recent years, intended specifically to consider the capabilities and characteristics of the digital smartphone technology and mHealth behaviour change app environments (Mohr, et al., 2015; Dick, O'Connor and Heavin, 2017). Examples of validated mHealth (behaviour change and intervention) app evaluation methods and tools increasingly utilised in empirical studies include: the Continuous Evaluation of Evolving Behavioural Intervention Technologies (CEEBIT) method (Mohr, et al., 2013); the Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018); the Sequential Multiple Assignment Randomised Trial (SMART) method (Collins, Murphy and Stretcher, 2007); and the Trials of Intervention Principles (TIPS) method (Mohr, et al., 2015). A critical comparison pinpointing the strengths and limitations of these three prominent mHealth evaluation methods has been carried out by Dick, O'Connor and Heavin (2017). Moreover, many authors also emphasise the importance of other non-clinical evaluation measures, particularly regarding the usability, user experience, usefulness and engagement of mHealth

apps (Pham, Wiljer and Cafazzo, 2016; Jake-Schoffman, Silfee and Waring, 2017; Blandford, et al., 2018; McCallum, Rooksby and Gray, 2018). All of these additional evaluation methods stem from an information systems perspective, rather than a health and medical sciences perspective. McKay, Slykerman and Dunn's (2019), for instance, have recently proposed the App Behaviour Change Scale (ABACUS) as a reliable and validated tool for testing and determining the effectiveness potential of mHealth behaviour change apps. More importantly and valuably, McKay and colleagues validated the ABACUS scale using physical activity behaviour change apps, indicating relevance and applicability to this study's research focus. As of date, ABACUS is the only validated scale that aims to measure and evaluate the potential for mHealth behaviour change apps. Somewhat similarly, the Mobile App Rating Scale (MARS) and the User Version of the Mobile App Rating Scale (uMARS) have also demonstrated validity and utility; although the MARS scale is orientated towards rating, measuring and evaluating the quality of mHealth apps over five broad categories, namely: functionality, engagement, aesthetics, information quality, and overall satisfaction (Hides, et al., 2014; Stoyanov, et al., 2015; Stoyanov, et al., 2016). On another note, in attempts to improve best practice standards for conducting and reporting on mHealth app research, the Consolidated Standards of Reporting Trials of Electronic and Mobile HEalth Applications and onLine TeleHealth (CONSORT-EHEALTH) statement and checklist (Eysenbach and CONSORT-EHEALTH Group, 2011; Eysenbach, 2013), and the mHealth Evidence Reporting and Assessment (mERA) checklist (Agarwal, et al., 2016), have been published. Subsequent to their release, the CONSORT-EHEALTH statement and checklist, and the mERA checklist have demonstrated success in improving the quality of reporting in mHealth behaviour change app intervention research, and have been useful for studies employing both RCT and other (non-RCT) evaluation methods (Tong and Laranjo, 2018; Edridge, et al., 2019; Hardeman, et al. 2019).

While keeping these points in mind, attention can return to *Step 6* of the mHealth intervention development process. Four of the seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category dedicate particular stages of their processes to conducting randomised controlled trials (RCTs). Approach #6 identifies Step 5 for "Randomised Controlled Trials". Approach #8's Stage 3 (Access) includes Phase 9 which specifies "Evaluate (for Efficacy in an Randomised Controlled Trial)". Approach #11 allocates Stage 4 for "Evaluation Trials", and Approach #12 defines Phase 3 "Clinical Trial Evaluation" in the "Clinical Development Stage" of its process. In comparison to these four approaches,

Approaches #7, #9 and #10 do not consider or include RCTs in their processes. All four approaches (Approaches #6, #8, #11 and #12) stipulate that RCTs be conducted with the aim of evaluating the efficacy and effectiveness of mHealth intervention apps in ideal circumstances and real-world contexts, respectively. On the one hand, from a health sciences perspective, the main quantitative objective outcome measures discussed by the approaches are related to changes in the target health behaviour, the health behavioural outcome(s), proximal health behaviours, or health-related behaviours that lie on the causal pathway of the intervention (such as mediators and moderators). Some of these objective measures may be related to the target health behaviour, such as in the case of physical activity which will measure quantity, frequency, intensity and duration of activity. Other objective measures for physical activity may relate to physiological variables, such as body mass index (BMI), body fat percentage, weight loss and waist-to-hip circumference ratio. Overall though, the cause-effect outcome measures from a health sciences perspective will be articulated and discussed in clinical and medical science terms. What is more is that, from a health sciences perspective, many mHealth app intervention evaluations may also aim to assess users' acceptance, adoption, adherence and usage of the intervention and its comprising intervention components or strategies (BCTs). Approach #6 is the only approach of the four that explicitly discusses conducting comparative studies across separate intervention components or strategies, as a means to assess and determine their effective potential relative to the whole intervention.

On the other hand, from an information systems perspective, the main outcomes measures are predominantly qualitative and subjective, but may also include quantitative and objective metrics. Measures to evaluate the effectiveness of mHealth apps from an information systems perspective will aim to assess and determine usability, user experience, user engagement and user satisfaction, as well as the acceptance, adoption and usage of apps by users. Approach #11 suggests utilising the Health Information Technology Usability Evaluation Model (Health-ITUEM) to assess mHealth apps from an information systems perspective. The essential difference between the health sciences perspective and the information systems perspective is that the former focuses on evaluating the intervention using health and clinical measures, whereas the latter focuses on evaluating the technological platform through which the intervention is delivered (that is, the design, features and functionalities of the mHealth app).

Other valuable contributions are noted by Approaches #6, #8, #11 and #12. Approach #6 discusses considering measuring adverse and unintended consequences which may result when

performing RCTs. Approach #6 is the only approach of the four that discuss the value in performing pragmatic RCTs. The authors of Approach #6 argue for pragmatic RCTs (also referred to as practical clinical trials) which focus on evaluating the correlations (associations) between interventions and outcomes in real-world contexts, rather than only focusing on causal (cause-effect) relationships. Furthermore, Approach #6 cautions that any recruitment issues faced during the pragmatic RCTs may be indicative of real world adoption issues. On another note, as mentioned in the discussion earlier, the capabilities and characteristics specific to the smartphone device and mHealth app environments are notably distinct to traditional clinical treatment and medical intervention settings. Approach #8 reinforces this argument by emphasising the importance in considering the "rapidly evolving nature of mobile technology and the time involved in carrying out a rigorous evaluation study" and that "digital intervention[s] may need to be continuously refined during the trial to ensure that it does not become obsolete by the time the trial is completed" (Mummah, et al., 2016, p.5). The authors of Approach #8 recommend aiming to strike a balance between incorporating novel technological advancements and software updates, and maintaining the internal validity of the RCT. Furthermore, as noted earlier, Approach #8 discusses utilising best practice guidelines and standards when performing and reporting on mHealth app intervention RCTs, such as the CONSORT-EHEALTH statement and checklist. Additional contributions are made by Approach #12 which stress the importance of other evaluation methods alongside RCTs, particularly methods which employ short-term, rapid, agile, adaptive and iterative approaches. The authors also discuss the value in reducing both the sample size and the duration of study procedure when performing mHealth app evaluations. The alternative evaluation method discussed most often by Approach #12 is Alpha and Beta Testing (A/B Testing). Approach #12 also repetitively mentions and makes reference to adaptive intervention designs for mHealth app trials [citing authors including Lin, et al. (2015); Bhatt and Mehta (2016); and Pallman, et al. (2018)], and touches on "continuous experimentation" methods which are often employed by digital technology and software companies (Kohavi and Thomke, 2017; Wilson, et al., 2018, p.5).

Once RCTs, RCT-adapted and/or other alternative non-RCT evaluations have been conducted, and results have been analysed, Approaches #8 and #12 underscore the value in performing one last refinement iteration to the mHealth behaviour change intervention app, prior to full real-world deployment and public implementation. Moreover, Approach #12 explicitly discusses that the final mHealth app intervention alterations, refinements and improvements

result in a "successful release candidate", ready for public commercial release on consumer app markets such as the Android Google Play and Apple iOS app stores. On a final note, at the end of Phase 3, Approach #12 suggests the multi- and interdisciplinary team make use of gating questions in determining whether an mHealth app candidate (product) demonstrates potential for success and is ready for release. A primary example of a gating question at this stage of the process is "Can we generate sufficient evidence to show that the mHealth app actually solves the defined health problem?".

All in all, *Step 6* shows that conducting trials and evaluation studies are imperative to the mHealth app intervention process, particularly since they primarily aim to establish whether an mHealth intervention app demonstrates evidence for bringing about a required (intended) change in individuals' health behaviour(s).

### *Step 7*

Subsequent to *Step 6* and carrying out RCT (or related) evaluation studies, three of the seven information systems and technology multi- and interdisciplinary approaches specify one additional stage in their respective mHealth app intervention development processes. These extra contributions are positioned and discussed under *Step 7*. More specifically, Approach #6 defines Step 6 which focuses on performing "Qualitative Follow-Up" studies. Approach #8 outlines Stage 4 (Share) which includes Phase 10 "Share". Approach #12 stipulates a Phase 4 referred to as "Post-Market Surveillance" in the "Clinical Development Stage" of the mHealth agile development process. The other four approaches, namely Approaches #7, #9, #10 and #11 do not identify or discuss any post-testing or post-evaluation steps in their processes.

Approach #6 defines Step 6 for conducting "Qualitative Follow-Up" studies, which aim to inform subsequent mHealth app intervention improvements, to determine whether there are any implementation issues, and to ascertain whether there may be any other effects if the intervention were to be scaled-up. Approach #6 suggests using qualitative methods such as interviews and online surveys for conducting these follow-up studies. Moreover, Approach #6 recommends assessing and determining whether the underlying theoretical foundations of the mHealth behaviour change app intervention demonstrates consistent real-world effects and evidence for changing the health behaviour of the target population group. The core intention behind these activities in Approach #6's Step 6 is similar to the intention driving Approach #12's Phase 4 "Post-Market Surveillance". According to Approach #12, the intention of a post-

market surveillance stage is to conduct ongoing user support and feedback, data analytics, technical maintenance of the mHealth app, and privacy and security monitoring. Ongoing user support and feedback is recognisable in public health apps on the consumer app market, which offer users the opportunity to submit reports regarding content issues, technical defect issues (commonly referred to as 'bugs') and violation concerns, or to simply submit reviews and suggestions for future app improvements and version updates. Data and web analytics, using services such as Google Analytics, provides app intervention designers and developers with the opportunity to track, monitor and predict users' app activity at certain points in time, during particular intervals of time, or over the lifespan course of the app. Data analytics and statistical analyses can offer insight into which components, features and functionalities of an mHealth app are most frequently engaged with, and for how long, which indirectly can be used to enhance the future potential of the app. Furthermore, Approach #12 emphasises that the multi- and interdisciplinary team remain up-to-date with technological advancements and software innovations, and also perform continuous monitoring and evaluation assessments of mHealth apps' relevance, usefulness, usage, safety, and evidenced real-world effectiveness. On an additional business related note, Approach #12 suggests that the ongoing maintenance costs and cost/benefit ratios are continuously monitored, calculated and evaluated over time. Similar to the other phases in its mHealth agile app development process, Approach #12 proposes a handful of gating questions which the multi- and interdisciplinary team can refer to and use in the post-market surveillance stage. Examples of gating questions include: "Is the mHealth app still relevant, safe and accurate?", "Is the mHealth app still valuable enough for users to justify its continued (future) developments and maintenance?", and "Can the mHealth app be further improved and updated?".

On a final note for *Step 7*, Approach #8 outlines Stage 4 (Share) which defines a final Phase 10 "Share" in the digital health intervention development process. The aim of Phase 10 is to "widely" share, publish and disseminate lessons learned and findings to both researchers (in relevant academic spheres) and industry developers (in real-world practice). Sharing of information may be through formal means (such as journal article publications) and less formal means (such as conferences, networking, collaborations). The intention behind this notion is to help bridge academic-industry divides, and contribute to advancements in the multi- and inter-disciplinary mHealth behaviour change app intervention arena. Furthermore, Approach #8 recommends that formal sharing through publications be articulated using existing evidence-based ontologies that offer a standardised language (comprising shared terminology and shared

definitions) for heterogeneous parties to interpret and understand. Examples of standardised language ontologies have been mentioned several times in this critical theoretical analysis, namely the CALO-RE Taxonomy and the BCTT v1 Taxonomy. What is more is that Approach #8 recommends not only sharing lessons learned and findings with academic and industry partners, but also with the broader public and app consumers. As consumers of publicly available mHealth apps, end users may provide valuable feedback and suggestions that can inform future improvements to mHealth app research and practice. On a final note, Approach #8 suggests that formal strategic partnerships be formed between interested parties to support ongoing improvements and (scaled-up) reach of mHealth behaviour change app interventions.

### *Summary of Process Steps and Activities: Information Systems and Technology Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.2.4, Figure Appendix I.3 provides a summarised high-level graphical illustration of the key themes and subthemes identified in the process steps (and activities) of the seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category.

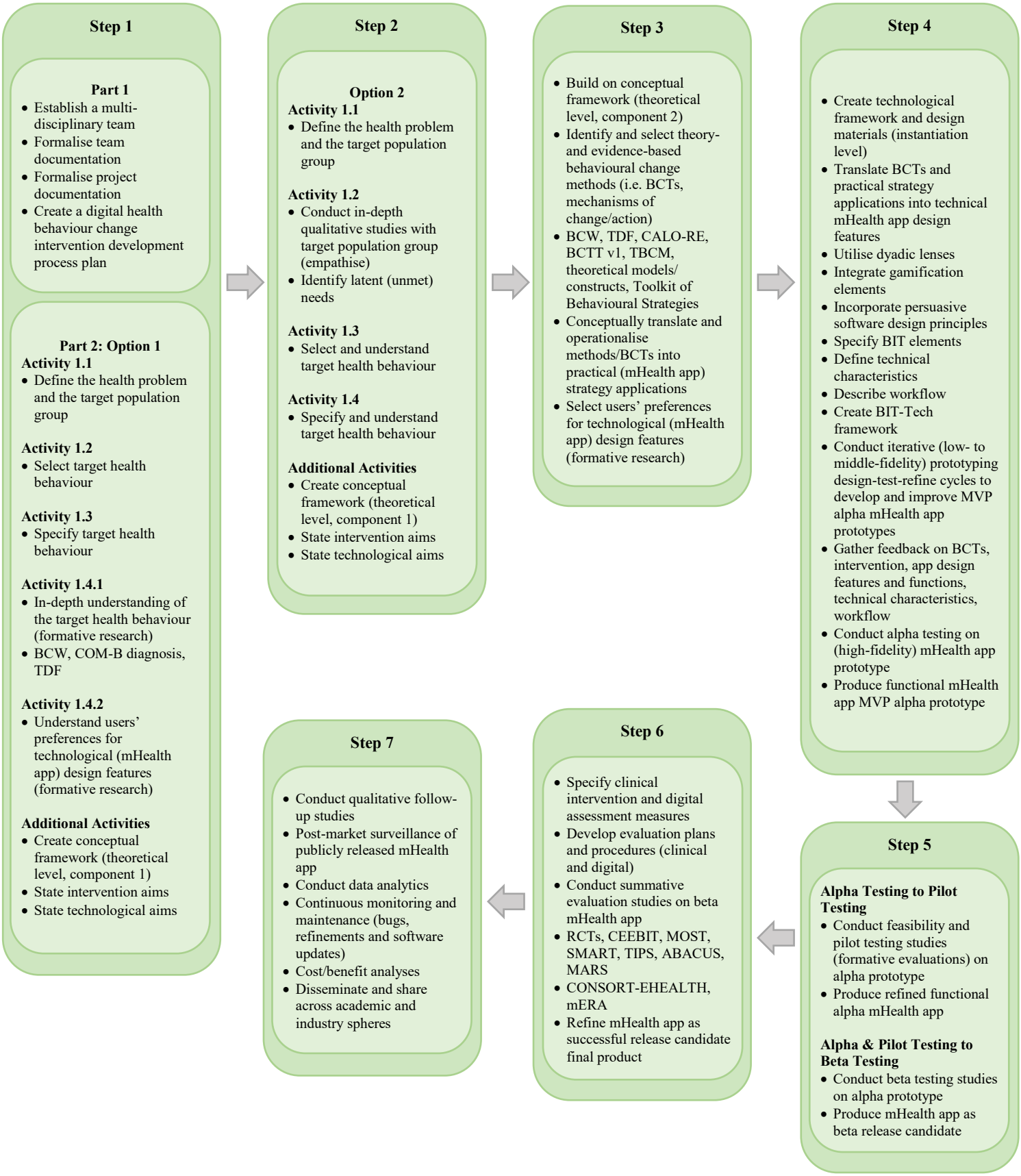



*Figure Appendix I.3: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Information Systems and Technology Perspective Category [Researcher's own construction]*

#### 6.4.2.5 Design Artefacts, Boundary Objects and Supporting Methods

*Step 1*

The first part of *Step 1* involves establishing and formalising a multi- and interdisciplinary team. The main outputs from this initial aspect of *Step 1* include: a project vision statement; a product vision statement and description (that is, of the mHealth behaviour change app); the initial project requirement specifications; the team requirement specifications; the signed team contracts; team protocols, guidelines and processes; a business model; the signed partnership agreements (with stakeholders and third-party members); the project funding particulars; the project resource requirements and particulars; a market analysis report (including an analysis of the consumers and the commercial smartphone app market); gating questions and answer report; and an overall process plan that all of the multi- and interdisciplinary team members can share and refer to guide them through each step of the mHealth behaviour change app intervention development process.

*Step 1 and Step 2*

For the second part of *Step 1*, this section discusses artefacts, objects and methods for Step *1* and *Step 2* together. The reason for this is that explicating the problem space can be approached from two perspectives. On the one hand, the team can first conceptualise and define the health problem, the target population group, and the mHealth intervention project. On the other hand, the team can commence by conducting qualitative research with participant representatives of the target population group, from which the result findings are used to inform the conceptualisation and definition of the health problem and the mHealth intervention project. Regardless of which approach is adopted, many of the artefacts, objects and methods referenced by the seven information systems and technology multi- and interdisciplinary approaches are the same or similar; all of which can be used to develop a deeper understanding of the problem space.

The main input artefacts, objects and methods used to inform the activities in *Step 1* and *Step 2* include: the Behaviour Change Wheel (BCW); the COM-B Model; the Theoretical Domains Framework (TDF); the socioecological model of health promotion (presented and discussed in Chapter 3); and the World Health Organisation's *Global Recommendations on Physical Activity for Health* (WHO, 2010). To support the team in gaining a better understanding of the health problem space, the target health behaviour and the target population group, six of the

information systems and technology approaches (with the exception of Approach #10) suggest reviewing relevant literature and similar empirical studies; using expert review and discussion methods; team brainstorming sessions; and using principles to guiding the selection and specification of a target health behaviour (Approach #8). Furthermore, qualitative and quantitative research methods and techniques (usually focus groups or interviews, but also questionnaires, surveys and observations) can be referenced and employed to perform primary empirical studies with participant representatives of the target population group. Formative research can help the team gain a deeper understanding of: the intended target population group's characteristics and demographics; their attitudes, feelings and thoughts regarding the health problem, the target health behaviour and the specified target behaviour; and their preferences and opinions concerning app design features, smartphone operating systems and technology usage.

For the second part of *Step 1* (covering a combined discussion on *Step 1* and *Step 2*) the main outputs predominantly informed by a health sciences perspective include: a statement of the health problem (in behavioural terms) and its context; a specification (table) outlining the health problem, its context and the intended target population group; a socioecological model representation (diagram) of the in-context health problem with the target population group nested in the centre; a list of possible target health behaviours suitable for addressing the defined health problem; a statement and description of the selected target health behaviour; a specification of the selected target health behaviour (detailing particulars and context information in relation to the intervention and preliminary intervention goal); a target health behaviour specification (table) which answers seven key questions (Approach #9); a target population group specification and description; a needs assessment of the target population group (including characteristics, demographics, contexts of use, and apparent and latent unmet needs, values and motivations); and a COM-B Behavioural Diagnosis table. The first five checkboxes in the first two categories ("empathise" and "specify") of the IDEAS Checklist can be confirmed and checked. In addition, the main outputs which incorporate an information systems perspective, include: a user state model (UML diagram) (illustrating the past, current and future states in relation to the user, intervention and aims); formative research (qualitative in-depth) findings report on the target population group (including smartphone usage behaviour, contextual factors influencing smartphone app usage, users' preferences for intervention change methods and techniques); and an app feature preference table (specifying users' preferences with supporting quotes from the focus group findings). More specifically,

in terms of the mHealth behavioural change intervention project, the main outputs include: a clear and concise statement of the broad mHealth intervention app goal; a statement and description of the mHealth behaviour change app's objectives; a specification statement of the mHealth app intervention's aims, including the clinical aims (that is, the health sciences perspective) and the usage aims (that is, the information systems perspective).

### *Step 3*

To carry out the activities in *Step 3*, the team uses the outputs from *Steps 1* and *2* together with new artefacts, objects and methods to create a theoretical and conceptual framework design of the mHealth behaviour change intervention app. This involves reviewing, identifying and selecting theory-based methods (change mechanisms) and BCTs (behavioural intervention strategies/components) suitable to the specified target health behaviour, the defined target population group, and the selected mode of intervention delivery (namely, the smartphone app platform). The boundary objects used by the team to facilitate and support this selection process include namely the: 40-item CALO-RE Taxonomy (Michie, et al., 2011); the BCTT v1 93-item hierarchically clustered taxonomy (Michie, et al., 2013); the Taxonomy of Behaviour Change Methods (TBCM) (Kok, et al., 2016); the IDEAS Toolkit of Behavioural Strategies (Approach #8); the Behaviour Change Wheel (specifically the BCW's intervention functions); and the Theoretical Domains Framework (TDF). Furthermore, the COM-B Behavioural Diagnosis table (output from *Step 3*) can used alongside the BCW and the TDF to create a Theory and Intervention Function Component Map (table), which can be later extended into a Theory-Intervention Function-BCT Map (table) by including the selected BCTs in the far-right column. To further support the theory-based methods and BCTs selection process, the team can employ methods that involve reviewing relevant literature and findings published from empirical studies, or by consulting with health psychologists (as knowledge experts) to review and verify the selected BCTs. While the methods thus far predominantly adopt a health sciences and health behavioural intervention perspective, methods from an information systems and user-centred design perspective can involve focus groups, interviews, questionnaires, surveys and expert discussions. Utilising these methods allows the team to perform primary qualitative research with participants of the target population group (or with knowledge experts) to ascertain users' preference themes and specific user taste preferences regarding their usage attitudes and behaviours towards the selected digital mode of delivery (the mHealth app platform), as well as the usability, user experience, aesthetics and acceptability of the mHealth

app's design features and instantiated (operationalised) components. Artefact and object inputs into this process can include referring to existing public commercially released mHealth apps that target the same health behaviour and the same (or a similar) target population group.

The main outputs for *Step 3* include: a list of the selected theory-based methods; a list of possible 'most promising' BCTs (evidenced to influence the determinants); a list of the selected BCTs (along with rationale justifying each BCT's selection); a report of any theoretical models, constructs, taxonomies or methods used by the team (along with rationale); a list and description of intrinsic process motivators (Approach #8); a Theory and Intervention Function Component Map (table); a Theory-Intervention Function-BCT Map (table); a Thematic User Preference table; a report on commercial smartphone ownership and mobile operating system usage statistics (based on the demographics and characteristics of the target population group); any documentation reporting on the procedures and findings from conducting primary qualitative studies with participants (or experts); an overall report document that can be shared, referred to and used by the all of the multi- and interdisciplinary team members, concisely and clearly identifying and describing the theoretical and conceptual framework design of the mHealth behaviour change intervention app. Additionally, the sixth and seventh checkboxes in the third category ("ground") of the IDEAS Checklist can be confirmed and checked by the team.

### *Step 4*

The core aim of *Step 4* is to translate the theoretical and conceptual design into a concrete and material design solution by employing prototyping methods and performing a series of iterative design-test-refine cycles, ultimately leading to the development of an alpha version of the mHealth behavioural change intervention app. Many of the outputs developed during *Steps 1* to *3* can be referred to, used and even expanded on by the multi- and interdisciplinary team when performing activities and producing outputs during *Step 4*. Methods and techniques employed by the team to perform the design activities in *Step 4* include: prototyping techniques (such as parallel prototyping or sequential prototyping); qualitative and quantitative user feedback and prototype testing methods (for example, information conversations, (online or paper-based) surveys, focus groups, usability tests, cognitive walkthroughs, think-aloud tests, user experience design tests, semi-structured interviews, or in-depth qualitative interviews); software alpha testing method procedures (along with guidelines for conducting white box testing, black box testing, and grey box testing sessions); brainstorming and creative idea

generation methods and techniques; divergent thinking techniques; agreed-upon guidelines and procedures for performing the prototyping cycles; and all necessary ethical guidelines, documentation and standard protocols. To further support the design solution translation and materialisation process, the team can employ methods and techniques that involve reviewing relevant literature and findings published from empirical studies, or can consult and liaise with consultants from commercial app companies and software engineering firms.

Artefacts, resources and materials that can be employed to act as boundary objects in facilitating and supporting communication and collaboration across boundaries include: a variety of prototyping materials (for example, paper, cardboard, whiteboards, pens, colour materials, computer-aided simulation software, et cetera); gamification models, taxonomies and principles; persuasive systems design principles (PSDM); the Health-ITUEM framework and criteria; quality assurance, privacy and security standards (Approach #12); accessibility standards (such as WCAG 2.0, W3C/WAI); a template of several gating questions that the team should aim to answer before transitioning to *Step 5* (Approach #12). Furthermore, the dyadic lenses (Approach #10) is another valuable boundary object that the team can refer to and utilise during *Step 4*, particularly since it was developed with the primary intention of providing intervention designers and developers (from both the health sciences and the information systems perspectives) with means to bridge cross-links between behavioural theory and BCTs into operationalised smartphone app design features. Moreover, the "Instantiation Level" of the BIT-Model provides an additionally valuable artefact that the team can refer to and utilise to guide them in designing and developing the BIT elements, the technological characteristics and the workflow.

The main outputs acting as design boundary objects and design artefacts that are produced during the prototyping process include: low-fidelity prototypes (such as design feature mock-ups, user interface screen mock-ups, storyboards, thumbnail sketches and wireframes); medium- and high-fidelity prototypes (such as interactive and clickable computer-aided software interfaces and functional simulations); brainstorming and creative outputs (such as idea generation products, board/wall displays, graphical and visual representations, models, sketches, mind maps); documentation detailing artificial prototyping scenarios; user feedback and testing documentation and finding analysis reports (summarising and highlighting users' feedback and improvement suggestions); a BCT-Gamification list; a persuasive systems design principles list; a BCT-UCD App Translation Map (table); an accept/reject user decision table

(with rationale for users' decisions); software engineering diagrams including the user journey flows and the intervention delivery flow (using UML modelling techniques and notation); a Content Specification table; a list of the BIT elements; a final intervention mapping table (Curtis, Lahiri and Brown, 2015, p.15, Multimedia Appendix 3); a BIT-Tech notation model and its associated calculations for the mHealth app developers [covering the intervention (I), aim (A), element (E), characteristics (C), workflow (W), data (D), and time (t)]; and a BIT-Tech report for the mHealth app developers (detailing the mHealth app's technical components, including the profiler, the intervention planner, the intervention repository, and the user interfaces). Some of the other main supporting artefacts produced during *Step 4* include: documentation reporting on the qualitative and quantitative methods used; applications and documents for ethical approval; answered gating questions (Approach #12); and a team document reporting on and summarising all of the alpha versioning decisions made throughout *Step 4*). Additionally, the eighth to twentieth checkboxes in the fourth, fifth, sixth and seventh categories ("ideate", "prototype", "gather" and "build") of the IDEAS Checklist can be confirmed and checked by the team. On a final note, the key design boundary object (artefact) produced by the end of *Step 4* is a high-fidelity functional prototype as an alpha version of the mHealth behaviour change intervention app (which can also be referred to as a functional MVP), which can be used as a common point of reference for all of the multi- and interdisciplinary team members to have a shared understanding of the concrete and material design solution.

### *Step 5*

The activities in *Step 5* use the outputs produced from *Step 4* along with other artefacts, objects and methods to pilot test and subsequently beta test the mHealth app prototype with target users. The main key input into *Step 5* is the alpha app version developed in *Step 4*, which together with employed pilot testing and feasibility testing methods and techniques, is used to iteratively assess the feasibility, integrity and reliability of the app, resulting in a final fully functional mHealth app ready for beta testing. Beta testing methods and guidelines are then referred to and utilised by the team to guide the beta testing process in real-world settings. Approach #9 also suggests consulting with various experts from the health sciences and information systems perspectives, as well as consultants from smartphone app companies, to gather additional input and experience-based insights, to further improve the beta release candidate (product). Other supporting input artefacts include the Health-ITUEM survey criteria

(which can be filled out at the end of a pilot testing period); quality assurance, privacy and security standards (Approach #12); accessibility standards (such as WCAG 2.0, W3C/WAI); a template of gating questions that the team should aim to answer before transitioning to *Step 6* (Approach #12).

The main outputs from *Step 5* include: reports on the results and analysis findings from the pilot and feasibility studies; documentation and protocols for the subsequent trial evaluations to take place in *Step 6* (including details pertaining to the trial study's design, data collection and technical considerations, as well as participant recruitment, enrolment, registration, retention and adherence); applications and documents for ethical approval; documentation outlining the deployment and implementation procedures; reports and summaries on expert consultations and feedback; documentation clearly tracking and reporting the mHealth app's version builds over time (using semantic numerical sequence-based identifiers); answered gating questions (Approach #12); and a multi- and interdisciplinary team document reporting on and summarising all of the pilot and beta versioning decisions made throughout *Step 5*). Additionally, the twenty-first to twenty-fourth checkboxes in the eighth category ("pilot") of the IDEAS Checklist can be confirmed and checked by the team. On a final note, the main output from *Step 5* is a refined and improved fully functional mHealth app prototype in the form of a "successful beta candidate" that is ready for large-scale public release and randomised controlled trial summative evaluations (to take place in *Step 6*).

### *Step 6*

All of the outputs produced in prior steps of the process can be used to inform the activities in *Step 6*, which is essentially focused on performing large-scale randomised controlled trials (RCTs) on the "successful beta candidate" ("beta release candidate"). New summative evaluation methods and techniques are employed at this stage to inform the RCT studies or RCT-alternative studies on the beta candidate. The team can use traditional RCT methods, pragmatic RCT techniques or "continuous evaluation" methods (Approach #12), although traditional RCTs are often highly criticised in the mHealth behaviour change app intervention context. Therefore, the team can refer to and employ newly adapted alternative evaluation methods particularised to the mobile and smartphone app platforms to perform trial studies on the beta mHealth app, including: the Continuous Evaluation of Evolving Behavioural Intervention Technologies (CEEBIT) method (Mohr, et al., 2013); the Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher,

2007; Collins, 2018); the Sequential Multiple Assignment Randomised Trial (SMART) method (Collins, Murphy and Stretcher, 2007); and the Trials of Intervention Principles (TIPS) method (Mohr, et al., 2015). Since these methods are predominantly from the health sciences perspective, the team can also refer to and employ other evaluation frameworks and scales that incorporate an information systems perspective, including App Behaviour Change Scale (ABACUS) (McKay, Slykerman and Dunn, 2019), the Health Information Technology Usability Evaluation Model (Health-ITUEM), the Mobile App Rating Scale (MARS) (Hides, et al., 2014; Stoyanov, et al., 2015), and the User Version of Mobile App Rating Scale (uMARS) (Stoyanov, et al., 2016). Furthermore, to improve best practice standards for conducting and reporting on the mHealth app trial studies, the team can refer to and use the Consolidated Standards of Reporting Trials of Electronic and Mobile HEalth Applications and onLine TeleHealth (CONSORT-EHEALTH) statement and checklist (Eysenbach and CONSORT-EHEALTH Group, 2011; Eysenbach, 2013) and the mHealth Evidence Reporting and Assessment (mERA) checklist (Agarwal, et al., 2016). Overall, the main outputs from *Step 6* include: documentation reporting on the details of the summative evaluation studies applied (including the study designs, participant particulars, study protocols and procedures, et cetera); reports on the results and analysis findings from the summative evaluation and trial studies; applications and documents with proof of ethical approvals; answered gating questions (Approach #12); and a multi- and interdisciplinary team document reporting on and summarising all of the large-scale trial evaluation decisions made throughout *Step 6*). Additionally, the twenty-fifth to twenty-eighth checkboxes in the ninth category ("evaluate") of the IDEAS Checklist can be confirmed and checked by the team. On a final note, the main output from *Step 6* is an updated and further refined "successful release candidate" (that is, an improved beta version) that is ready for public commercial release (or version update) on consumer app markets such as the Android Google Play and Apple iOS app stores.

### *Step 7*

In *Step 7* the team uses a variety of methods and techniques to perform post-market surveillance activities and qualitative follow-up studies with real-life mHealth app users (whom have downloaded and used the commercially-released app from consumer app stores). Methods and techniques that the team can use to perform qualitative follow-up studies generally include interviews and online surveys and questionnaires. To carry out post-market surveillance activities, the team can make use of data analytics (such as Google Analytics) to monitor users'

engagements with and issues encountered when using the app in real-world contexts, and can also use statistical analysis methods to calculate the ongoing maintenance costs and cost/benefit ratios of the app over time (related to the business perspective). Other artefacts inputs and outputs can relate to sharing, publishing and disseminating the lessons learned and findings from the mHealth app intervention development process, available to both academic research and commercial industry partners. The team is encouraged to make use of evidence-based cross-disciplinary ontologies and taxonomies that offer a standardised language, so that as many interested parties as possible are able to interpret and make sense of the report publications and study findings. The main outputs from *Step 7* therefore include: reports and documented summary findings on the qualitative follow-up studies (including the study designs, protocols, ethics, procedures and methods used); post-market surveillance reports (for example, on data analytics, technical defect issues, content issues, violation concerns, and user feedback reports and improvement suggestions); and published artefacts (such as journal articles and conference papers) on the lessons learned and recommendations for future mHealth behaviour change app intervention development projects. Furthermore, the twenty-ninth to thirty-second checkboxes in the tenth category ("share") of the IDEAS Checklist can be confirmed and checked by the team.

### *Summary of Summary of Design Artefacts, Boundary Objects and Methods: Information Systems and Technology Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.2.5, Figure Appendix I.4 provides a summarised graphical illustration of the key artefacts, design boundary objects and supporting methods identified as inputs and outputs into the process steps (and activities) of the seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category.

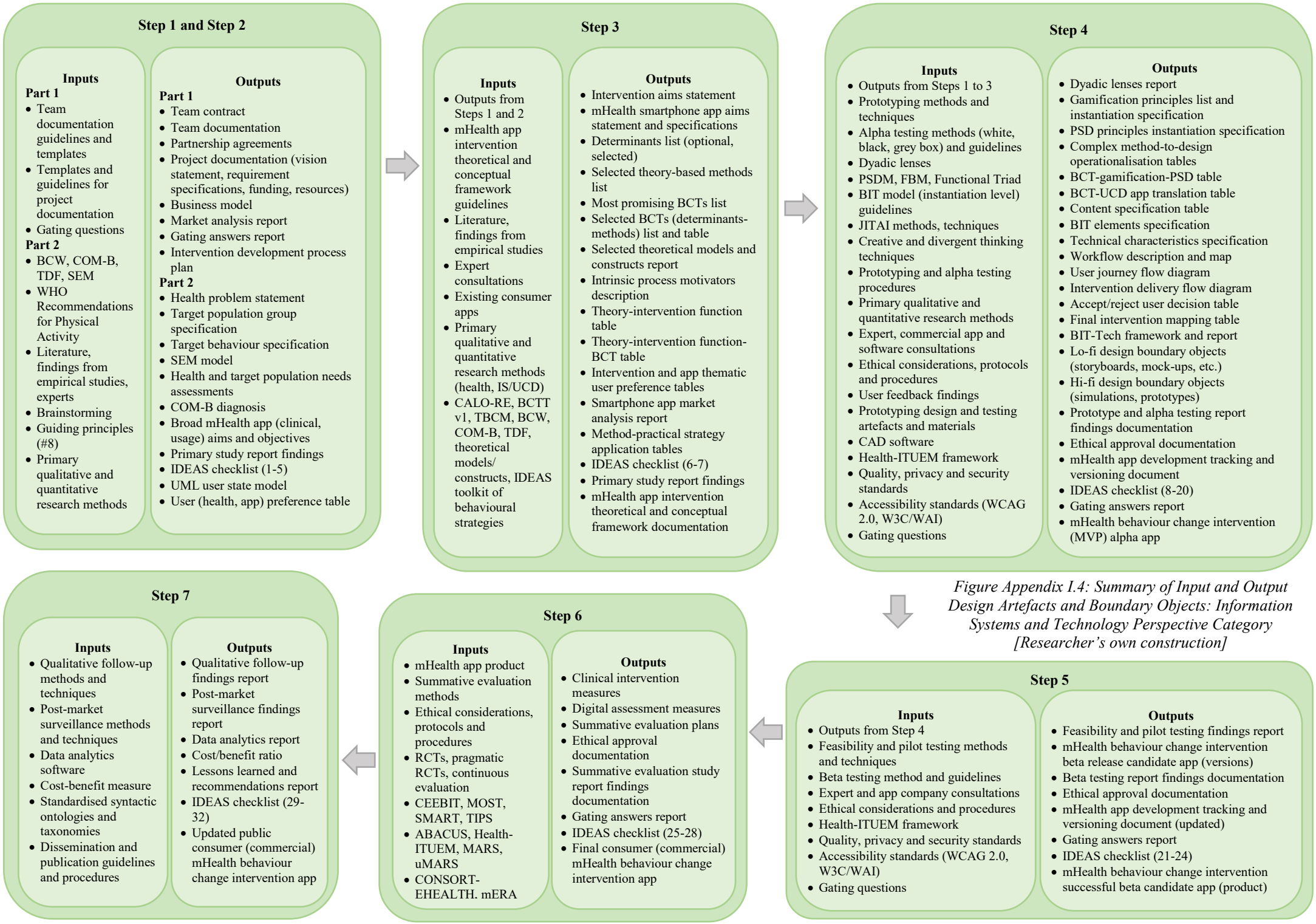



*Figure Appendix I.4: Summary of Input and Output Design Artefacts and Boundary Objects: Information Systems and Technology Perspective Category [Researcher's own construction]*

#### 6.4.2.6 Knowledge Boundary Contributions

All seven of the multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category latently and explicitly argue for the transfer, translation and transformation of knowledge across heterogeneous community boundaries as a necessary and integral requirement for the enhanced design of smartphone mHealth (promotion) behaviour change intervention apps. However, of the other seven approaches, Approaches #6 and #11 discuss knowledge-related content the least, and make no mention of concerns regarding multi- and interdisciplinary team communication, collaboration, cooperation, negotiations or power dynamics. In comparison, Approaches #7, #8, #9, #10 and #12 all explicitly articulate differences and dependencies in the knowledge, skills, expertise, goals, interests and activities contributed by various participating multi- and interdisciplinary team members. Approach #7, for instance, expressly recognises that both health behavioural sciences experts and technology/information systems experts offer valuable knowledge, expertise and skill contributions to the design of mHealth behaviour change apps, and that differences in knowledge and training backgrounds informs the use of different conceptual and practical models when designing, developing and evaluating mHealth behaviour change apps. Approach #8 also discusses the importance of diverse knowledge, expertise and skill contributions, and emphasises how thought diversity prompts the generation of highly divergent ideas and app prototype instantiations, which has shown to lead to more creative, innovative and efficacious final output mHealth behaviour change intervention app design solutions. With this being said, for heterogeneous disciplinary and specialist knowledge, expertise and skill contributions to synergistically positively enhance the overall design of an mHealth app, differences in worldview perspectives, language use, interpretations of meaning, goals and interests need to be explicitly articulated and acknowledged by all participating team members.

Differences in the representation of knowledge and how language and terminology is stored, transferred and retrieved operates at a syntactic level. A common lexicon and other standardised language artefacts are examples of syntactic boundary objects that, when employed by heterogeneous team members, provides a vocabulary for facilitating dialogue transfer and cross-boundary team communication (Carlile, 2004). Without explicitly referencing knowledge boundary or syntactic artefact theory, Approach #7 openly argues for the development and use of detailed ontologies to facilitate the interchange of information across collaborating heterogeneous communities of practice. Approach #7 goes on by explaining that well-defined and agreed-upon (consensus) ontologies are necessary for

providing team members with a formalised language that on the one hand, contains consistent descriptions of data and information at various levels of detail, and on the other hand, remains independent of particular jargon (specialised names and labels). This use of common language and dialect allows for the effective storing, querying and retrieving of data and information in structured ways, which in turn enables cross-boundary communication and knowledge transfer within the multi- and interdisciplinary team. Similar to Approach #7, Approach #9 discusses the value in utilising syntactic boundary objects, and explicitly discusses the Behaviour Change Wheel (BCW) (a health psychology-based method for characterising interventions and analysing health behaviours) as based on a standardised language of theoretical constructs and BCTs, specifically the BCTT v1 taxonomy (Michie, et al., 2013). According to other health behavioural change intervention authors, additional common language objects include the CALO-RE Taxonomy (Edwards, et al., 2016), the COM-B Model (Barker, Atkins and de Lusignan, 2016) and the Taxonomy of Behaviour Change Methods (TBCM) (McHugh, et al., 2018).

In transitioning from the syntactic knowledge boundary to the semantic knowledge boundary, Approach #7 recognises the value in utilising formalised shared processes and methods as tools for facilitating knowledge translation and guiding team members when designing, developing and evaluating mHealth behaviour change apps. On a similar note, Approach #12 implicitly references the semantic knowledge boundary in its strongly asserted suggestion that all participating team members be actively and continuously engaged in an iterative design, development and evaluation process that is "built on a common foundation of guidelines and recommendations" (Wilson, et al., 2012, p.2). Approaches #9 and #12 emphasise that engaging in a collaborative co-design and co-development process requires frequent and consistent face-to-face interactions, communications and negotiations between all participating team members and interested parties; yet neither approach elaborates on how these engagements can be achieved in practice. Furthermore, Approach #12 itself (as a multi- and interdisciplinary approach) provides a shared process operating at a semantic knowledge level, particularly in its offering as an integrated combination of methods from a variety of heterogeneous, yet relevant, disciplines, including methods from agile systems design and development, user-centred and user experience design, product development and clinical trial research. Approach #8, in addition, references the use of the CONSORT 2010 Guidelines (as a shared semantic tool), which provides the team with evidence-based consolidated standards for reporting on evaluation trials (Moher, et al., 2010). Notably however, as a criticism of Approach #8, the

more recently published CONSORT-EHEALTH checklist is better suited than the original CONSORT statement as it provides an instrument for guiding the reporting of eHealth, web-based and mHealth interventions specifically (Eysenbach and CONSORT-EHEALTH Group, 2011; Eysenbach, 2013). Nevertheless, in keeping with the analysis discussion on semantic knowledge translation, Approach #10 overtly discusses the differences in language use and interpretation of meaning between heterogeneous disciplinary arenas, specifically between the fields of health psychology and health sciences on one side, and the fields of persuasive technology and persuasive systems design on the other side. According to Approach #10, both sides utilise different taxonomies (referring specifically to the BCTT v1, FBM and PSDM) which contain different definitions and framings, yet together can be encased as falling under a shared umbrella of "motivational features" (Geuens, 2019, p.350). Design and development issues arise when different "reductionist and naïve" interpretations of meaning inform and result in different "oversimplified … decontextualized [and] discrepant" operationalisations of theory-based strategies and principles (Geuens, 2019, p.351). Approach #10 proposes a set of dyadic lenses to address the two sides' different interpretations of meaning, and establishes cross-links for clarifying ways intervention designers and developers can implement and instantiate strategies and principles, yet simultaneously remains respectful to the different fields' knowledge specialisations. The dyadic lenses therefore offer an implicit representation of interpretative flexibility; a key quality of knowledge boundary objects. On another note though, critical observation reveals none of the seven approaches as recognising differences in the interpretation of meaning of essential mHealth app design terminology, particularly the different ways heterogeneous disciplines interpret words such as 'usability', 'adherence', 'acceptance', 'adoption' 'satisfaction' and 'user experience', based on their different knowledge backgrounds and worldview conceptual and mental models. In sharp contrast to these seven approaches in the Information Systems and Technology Perspective category, Approach #13 (in the Partnership Perspective category) does overtly recognise, discuss and distinguish between the different interpretations of meaning of such terminology.

In progressing from a semantic level to a pragmatic level, all seven multi- and interdisciplinary approaches discuss the creation and iterative refinement of mHealth app prototype versions as integral to the development process, yet none of them consciously recognise prototypes as valuable design boundary objects for supporting and facilitating the transformation and generation of new knowledge. Notably though, Approaches #8 and #12 latently recognise the how conflicts of interest and negotiations operate at a pragmatic knowledge level. Approach

#8 discusses how plentiful practical issues begin to surface when multi- and interdisciplinary team members collaboratively and cooperatively engage in the concrete and material mHealth app prototype building process. As these issues arise, team members are required to clearly communicate, negotiate and come to numerous consensus decisions regarding the app prototype's design and development. Since all of the heterogeneous team members are able to offer valuable alternate knowledge, expertise and skill contributions to the app prototype building process, Approach #8 suggests the multi- and interdisciplinary team actively aim to "properly balance and reconcile" all of the different perspectives and tenets throughout the decision-making process. Approach #8 specifically recommends aiming to negotiate and balance the various perspective influences of "behavioural theory, user needs and desires, and technical, financial and practical feasibility", which quintessentially represent the goals and intentions of specialists from the fields of health psychology, health behavioural science, information systems, user-centred design and mobile smartphone app design and development. In other words, Approach #8 latently recognises that different perspectives are likely to result in conflicts of interest at a pragmatic knowledge level, and that app prototypes provide a pragmatic boundary object for facilitating negotiations and decision-making between multi- and interdisciplinary team members, and that as a result of such discussions and consensus building, new design knowledge can be iteratively generated and constructed in tangible and material forms throughout the app prototype building process. Moreover, Approach #8 discusses differences in interests and goals with regard to the number of BCTs and app design features that should be incorporated in mHealth app prototypes, and that there is often a misconception that 'more is better' and 'more is most effective'. Once again, open communication, collaboration and cooperation amongst team members becomes necessary to successfully negotiate how different, and at times opposing, priorities will be weighted and addressed (Approach #8).

On a somewhat similar note, Approach #12 discusses differences and conflicts in interests between smartphone app designers and developers in industry and clinical and health intervention researchers in academia. App designers and developers perceive resource investments in research as "slow[ing] down innovation", whereas clinical and health researchers assert that resource investments in research are paramount, particularly as "regulatory processes mature and move toward legislation" consequently influencing the quality, privacy and safety protocols governing the mHealth app industry. In light of these conflicting interests, Approach #12 proposes a multi- and interdisciplinary approach with the

aim of "meshing research and [mHealth app] development as seamlessly as possible … and help[ing] developers improve and continuously iterate their solutions based on research evidence [and theory]" (Wilson, et al., 2018, p.2). In addition to Approaches #8 and #12, Approach #7 touches on the value of transparently sharing and formalising intentions (that is, aims/goals) in terms of both health behaviour change intervention and mHealth app design perspectives, therefore latently reflecting the pragmatic knowledge level. Approach #7 discusses how using mutually shared checklists, flow diagrams and models (operating as knowledge boundary objects) can help facilitate clear communication regarding team members' different design intentions (aims/goals) for an mHealth app, and can help support the exchange and generation of creative and new ideas, ultimately transforming knowledge and advancing growth in the evolving mutli- and inter-disciplinary mHealth behaviour change app intervention arena.

#### 6.4.2.7 Limitations and Lessons Learned

Limitations, gaps, weaknesses and lessons learned can be identified across all seven of the multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category. The following short discussion does not provide an extensive critical analysis on all possible limitations or lessons learned, but instead touches on a few noteworthy points given the adopted theoretical lens (boundary object perspective) utilised to frame the conducted cognitive thought trials and judgement-making processes. With this being said, an initial cross-comparison reveals lessons learned regarding the characteristics, limitations and capabilities of the smartphone app platform as a selected mode of intervention delivery. An example of a (potential) limitation is that the rapidly changing and emerging technological advancements in the smartphone app environment requires that intervention designers and developers perform continuous and frequent software updates to their commercially published mHealth apps. Examples of digital and technical capabilities of the smartphone app platform relates to its in-built sensors (such as accelerometers, gyroscopes and GPS receivers) that allow for quantitative measuring and monitoring of users' physical activity engagement levels, as well as its customisable nature that allows mHealth apps' information, recommendations/suggestions, push notifications, messaging content and user profiles to be tailored and personalised to suit the app users' demographics and taste preferences. On an important note related to the digital smartphone app platform is the provision of guidance for translating, operationalising and instantiating BCTs and BIT elements into interactive mHealth app design features. Only three of the seven approaches, namely Approaches #7, #8 and #9,

provide sufficient guidance for how to operationalise and instantiate BCTs and BIT elements into mHealth app design features. This is a noteworthy weakness of the remaining four approaches given the important role materialisation and instantiation plays in designing and developing effective mHealth behaviour change apps. On another note though, Approach #7 provides valuable lessons learned in its contribution with the BIT and BIT-Tech models. The other six approaches, in comparison, are limited in their failure to recognise and incorporate technical- and instantiation-related considerations such as those proposed by Approach #7's BIT and BIT-Tech models. Moreover, in terms of application context, lessons can also be learned and insights gained from the case applications that apply Approaches #6, #7, #8 and #10 as processes for guiding the design, development and evaluation of mHealth physical activity behaviour change apps including: *Active Coach* (Simons, et al., 2018) (which applies Approach #6); *MyFitnessPal* (Mohr, et al., 2014), *HelpMeDot!* (Matthews, et al., 2017), and *TODAY* (Direito, et al., 2018) (which apply Approach #7); *Puzzle Walk* (Lee, et al., 2018) (which applies Approach #8); and *30 Day Fitness Challenge*, *Step Counter*, *Nike+ Running*, *Fitocracy* and *Endomondo* (Geuens, et al., 2019) (which all utilise Approach #10). In comparison to the lessons learned and insights gained from these mHealth apps that are particularised to the physical activity behaviour change context, Approaches #9, #11 and #12 are not applied to physical activity specifically, and therefore are limited in their provision of lessons learned. However, all seven approaches provide lessons learned in that they are orientated towards the dual intra-(primary)interpersonal level of sociological health promotion intervention, and although they all consider other influential external and environmental factors, the key focus is given to promoting the self-management of health behaviour on an individualised and social networking/social connectivity level.

In terms of the nature of the information systems and technology approaches, Approaches #7, #8, #9 and #12 offer lessons learned in adopting an agile, dynamic and rapid cyclical approach to mHealth app intervention design and development. More specifically, valuable insights are gained from the discussions on rapid prototyping and user testing; processes which have shown to be applicable and useful in the multi- and interdisciplinary mHealth app design space. In comparison to Approaches #7, #8, #9 and #12, Approaches #6, #10 and #11 do not propose agile and/or rapid cyclical approaches to mHealth app design, development and evaluation testing, which is a noteworthy limitation and weakness of these three approaches. Related to the nature of the approaches are the perspectives they offer. Insights are gained from Approaches #11 and #12 that incorporate the business perspective, which considers elements

concerning the commercial, product development and consumer markets. Business and product development perspectives are valuable in their applicability to the commercial smartphone app industry and consumer app market stores. In addition, Approaches #7 and #10 provide valuable lessons learned in their integration of persuasive technology and persuasive systems design perspectives, whereas Approaches #6, #8, #9, #11 and #12 are limited in their failure to recognise and leverage the power of persuasive strategies and principles in designing and developing influential mHealth behaviour change intervention apps. Furthermore, all seven information systems and technology approaches provide insights into their orientations toward systems thinking, software engineering and digital platform-related perspectives.

Further related to the approaches' natures and perspectives are their proposed and prescribed steps, stages, components and activities. In terms of mHealth app prototype testing, Approach #12 offers a significant lesson learned in its integration of Alpha Testing and Beta Testing methods. In contrast to Approach #12, Approaches #6, #7, #8, #9, #10 and #11 are limited in their failure to recognise these two testing methods. However, while acknowledging the valuable contribution offered by Approach #12 concerning Alpha Testing and Beta Testing, more recent publications have suggested a movement towards what is referred to as Delta Testing, which Approach #12 does not recognise or discuss. Given the evolution of consumer expectations and continuous advancements in the cutting-edge digital technology landscape, software design and development teams experience pressure to not only provide consumers with 'what they want', but to deliver these wants 'faster than competitors' (Centercode, 2019a). This has driven teams to prioritise drumming up the delivery of new updates and releases as frequently and quickly as possible, whilst trying to balance reliability, quality, user satisfaction and user experience (Centercode, 2019a). The focus within software environments, such as the smartphone app design and development arena, therefore often shifts towards adopting delivery-focused strategies and processes such as agile development, continuous integration and continuous delivery (Rader, 2019). While the intention behind employing these delivery-focused strategies is to improve consumer experience at a quicker pace, their application in practice is often at the expense of quality, which ironically ends up reducing, rather than enhancing, consumer experience (Centercode, 2019a). An example of this would be prematurely releasing an mHealth behaviour change app update with a new feature that still contains bugs and creates for negative consumer experiences. Delta testing provides a way of striking a balance between the demanding pace of continuous delivery and the generation of ongoing consumer (end user) feedback in a post-market stage (Naeem, et al., 2015). More

advantageously, delta testing runs alongside agile development processes, therefore allowing design and development teams to continuously design, build, test and iterate on new releases over time (Centercode, 2019a). This is a valuable testing method in the smartphone mHealth behaviour change app environment as it facilitates post-launch customer validation for every new build/new feature (Centercode, 2019b). "Delta" essentially refers to the difference between a live version and what is in the backlog (Rader, 2019, p.1). Delta testing is similar to modern beta testing practices in that it supports product (app) development using consumers' inputs based on real-world feedback and use cases (in real life contexts and environments). However, delta testing is distinct from beta testing in that its practices and processes leverage continuous planning and ongoing consumer engagement (rather than time-boxed engagement), occur during the post-launch (rather than pre-launch) phase of the product's development life cycle, and aim to spotlight test specific prioritised features and topics (rather than the holistic set of features) (Centercode, 2019a). This tightly-scoped approach to software app feature testing allows design and development teams to perform impactful and meaningful (prioritised) test objectives at short notice, within sprint timeframes, without having to map full-feature (deprioritised) test objectives beforehand (Centercode, 2019a). Delta testing is useful in that it supports and prioritises the continuous delivery of smartphone app updates and improvements throughout the maturity phase of the product's development life cycle by focusing on gathering immediate consumer feedback (including bugs, issues, ideas and praise) regarding an app's latest features, fixes and quality enhancements (Centercode, 2019b). Delta testing is also valuable in that it helps bridge the gap between the speed of continuous delivery and the quality of new releases, while avoiding costly outcomes (such as higher support costs and lower consumer satisfaction) (Centercode, 2019a). Notably though, delta testing methods should not be employed to replace alpha and beta testing methods; particularly given that each of these testing practices aim to achieve different goals and objectives, and operate at distinctly different stages of the product development life cycle (Rader, 2019). In a nutshell, considering the points discussed, the failure of all seven multi- and interdisciplinary approaches in the Information Systems and Technology Perspective category to acknowledge, mention or incorporate delta testing practices and processes is a noteworthy limitation and lost opportunity; consequentially associated with increased support costs, reduced consumer satisfaction, unsustainable adoption and adherence, and ultimate app ineffectiveness.

Furthermore, notable limitations with regard to summative evaluation methods are identifiable in Approaches #7, #9 and #10 which do not mention or include the use of RCTs in their

processes. While acknowledging this limitation, although traditional RCTs are criticised as having several limitations and impracticalities to the mHealth app context, they ultimately remain the medical gold standard for objectively trial testing the effectiveness of health interventions, and therefore should at least be recognised by researchers and practitioners in the mHealth behaviour change app intervention field. On the flipside of traditional RCTs, a critical analysis reveals insights gained and lessons learned regarding more recently proposed evaluation methods, tools and instruments that are better suited to the mHealth app context, including, namely: the Continuous Evaluation of Evolving Behavioural Intervention Technologies (CEEBIT) method; the Multiphase Optimisation Strategy (MOST) method; the Sequential Multiple Assignment Randomised Trial (SMART) method; the Trials of Intervention Principles (TIPS) method; the App Behaviour Change Scale (ABACUS); the Mobile App Rating Scale (MARS); the User Version of the Mobile App Rating Scale (uMARS); and the Health Information Technology Usability Evaluation Model (Health-ITUEM). Furthermore, insights are gained and lessons are learned regarding the standards of reporting on evaluation trial studies for mHealth apps, with reference to instruments and tools such as the Consolidated Standards of Reporting Trials of Electronic and Mobile HEalth Applications and onLine TeleHealth (CONSORT-EHEALTH) statement and checklist, and the mHealth Evidence Reporting and Assessment (mERA) checklist.

On another note, Approaches #6, #8, #9 and #12 are comparably more time and resource intensive than the other three approaches, especially considering the comprehensive multi- and interdisciplinary and stakeholder involvement, the extensive input required to design, develop and evaluate the mHealth behaviour change intervention apps, and the timeframes for sharing, publishing and disseminating knowledge across academic and industry spheres. Furthermore, in keeping with the mention of resource demands, all seven information systems and technology approaches are limited in that they require (and implicitly assume) all of the participating multi- and interdisciplinary team members to possess a sufficient, yet significant, amount of specialist knowledge, skill and expertise in order to interpret, make-sense-of, understand and apply the respective steps/stages and activities of their proposed processes. This implies a need for considerable past experience and substantial tacit knowledge and understanding, which in turn discourages and hampers the adoption, use and application of the seven approaches by inexperienced, untrained and amateur mHealth (promotion) behaviour change app intervention designers and developers.

Lastly, a critical cross-comparative analysis of all seven multi- and interdisciplinary approaches reveals none of them as recognising or discussing any concepts or constructs regarding community of practice theory, boundary object theory and knowledge boundary theory. Similar to the discussion on the "limitations and lessons learned" under Subsection 6.4.1.7 on the health sciences multi- and interdisciplinary approaches, this noteworthy theoretical comparative analysis finding offers both a valuable insight and a weakness. On the one hand, it demonstrates a noteworthy gap in the existing knowledge base. On the other hand, it verifies novelty in that the proposed boundary object view offers a novel perspective to addressing the identified multi- and interdisciplinary design issues in the emerging mHealth behaviour change intervention app arena. The theoretical framework (lens) is advantageous in its originality, yet disadvantageous in that the identifiable and extractable comparative and thematic analysis findings from the seven information systems and technology multi- and interdisciplinary approaches are, for the most part, latent and implicit, hence inherently lessening and limiting the richness of the generated themes. On a closing note, a handful of other noteworthy limitations, gaps, weaknesses and lessons learned can be referred to in Table B under Appendix H; although, to reiterate, these points are neither copious nor comprehensively extensive.

### 6.4.3 A Critical Analysis of Multi- and Interdisciplinary Approaches: A Partnership Perspective

Multi- and interdisciplinary approaches that offer a predominant partnership perspective are important to review because they provide insight into the ways digital health behaviour change interventions, and apps in particular, can be designed, developed and evaluated through active collaboration and participatory efforts. By collaboratively engaging with heterogeneous practice communities in the project team, a variety of knowledge, expertise, skills and practices, as well as different perspectives, opinions and suggestions can be contributed towards improving the output design solution and effectiveness potential of an mHealth app product. Other collaborative, participatory and partnership efforts can involve end users (as representatives of the target population) and external third party stakeholders (such as mobile app development consulting companies, cultural experts and business managers). The Partnership Perspective category includes a review of approaches that emphasise: the co-design, co-creation, co-development, co-production, co-evaluation and co-implementation of health interventions (Approaches #14 and #15); the participatory design of health behaviour change interventions (Approach #14); a user-centred/target audience-based approach to digital

health behaviour change intervention development (Approaches #14, #15 and #16); and a person/human-centred approach to digital health behaviour change intervention development (Approach #13). Overall, all four approaches provide insight into collaborative, participatory and partnership themes and subthemes that are valuable to the multi- and interdisciplinary mHealth physical activity behaviour change intervention app design, development and evaluation process.

The template criteria (Table 6.5) is used to critically analyse each of the four approaches. Table C in Appendix H provides a full detailed summary analysis of the partnership approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the four approaches, presented in a written report discussion. Box 6.6 identifies the four multi- and interdisciplinary approaches classified in the Partnership Perspective.

- **Approach #13** The Person-Based Approach for Developing Digital Health Behaviour Change Interventions
- **Approach #14** Participatory Design Approach for Stakeholder Engagement in Quality Health Behaviour Change Intervention Development
- **Approach #15** Co-Design Approach for Developing Tailored mHealth Behaviour Change Intervention Apps
- **Approach #16** Multidisciplinary Thematic Seminars as a Collaborative Design Method for Health Information Systems Development

*Box 6.6: Multi- and Interdisciplinary Approaches: Partnership Perspective*
*[Source: Researcher's own construction]*

#### 6.4.3.1 Aims and Contexts of Partnership Perspective Approaches

The four multi- and interdisciplinary approaches categorised in the Partnership Perspective share a common aim: *to involve, accommodate and engage collaborative and participatory contributions throughout the design, development and evaluation process, ultimately leading to the production of a collaborative technology-based health intervention*. All four approaches aim to provide guidance by employing and adapting collaborative and/or participatory methods and techniques borrowed from qualitative research as well as human-centred, user-centred and/or user experience design approaches. Approach #13 aims to guide the development of digital health behaviour change interventions by using in-depth qualitative research methods that focus on ascertaining, understanding and accommodating the psychosocial contexts and user experience perspectives of the target population. Approaches #14 and #15 aim to

incorporate collaborative and participatory design methods that emphasise the co-design, co-development, co-evaluation and co-implementation of health behaviour change interventions, with various interested stakeholders and target end user representatives. Approach #16 aims to provide guidance for the collaborative design and development of health information systems by involving various stakeholders and end user representatives in a cooperative multi- and interdisciplinary work environment.

Approach #13 aims to guide the development of digital health behaviour change interventions in general, including mHealth apps. Approach #15, in comparison, is aimed at the mHealth app platform specifically, while Approach #16 is aimed at guiding the collaborative development of health information systems, and not mHealth intervention apps specifically. In contrast to these three approaches, Approach #14 aims to provide a participatory design approach for developing "quality" health behaviour change interventions in general, regardless of whether they are intended for delivery via digital technology platforms or not (Carvalho, Jun and Mitchel, 2017, p.7). Furthermore, on the one hand, two of the four approaches, namely Approaches #13 and #15, have been used to target physical activity behaviour change in particular. For example, Approach #13 and Approach #15 were used to guide the development of the *HelpMeDot!* (Matthews, et al., 2017) and *OL@-OR@* (Verbiest, et al., 2018) physical activity apps, respectively. On the other hand, Approaches #14 and #16 were developed to target the medical and healthcare contexts, although notably, both can provide valuable insights and lessons learned for the collaborative and participatory design, development and evaluation of mHealth physical activity behaviour change intervention apps.

In terms of target audience, Approaches #13 and #15 have been applied to the individual and interpersonal socioecological levels of health promotion, and Approaches #14 and #16 have been applied to the organisational socioecological level. Overall, all four of the approaches aim to provide multi- and interdisciplinary guidance by stressing collaborative, cooperative and participatory team involvement and discuss the use of methods, artefacts and objects to support collaborative partnership efforts. Only two of the four approaches (Approaches #13 and #14), however, review and/or draw from existing approaches, including *Intervention Mapping* (Approach #1) and *The MRC Guidance for Developing, Evaluating and Implementing Complex Health Interventions* (Approach #3).

For purposes of length, the Partnership Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.3.2 to 6.4.3.7 are extracted to Appendix I.

One summary table and two summary figures for the Partnership Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

#### 6.4.3.2 Actors and Community of Practice Members

Multi- and interdisciplinary approaches within the Partnership Perspective category recognise a diversity of actors and community of practice members as participating in the health intervention development process. Notably, all four approaches emphasise that target population (end user) representatives be actively and collaboratively involved at all stages of the design, development and evaluation process. These approaches essentially orientate their focus to purposefully accommodate and understand the various needs and preferences of potential health intervention users, and stress the value that target representatives can directly contribute as active participants of the process. Terms frequently used to describe such direct participant engagement and partnership involvement include co-definition, co-design, co-creation, co-development, co-production, co-evaluation and co-implementation. One approach, Approach #15, refers to target end users as "customers" of digital health intervention products. Three approaches, with the exception of Approach #15, use the term "practitioner" to describe practicing healthcare professionals. All four Partnership approaches explicitly mention "stakeholders", although the specific actors they refer to in using the term "stakeholders" differs between the four approaches. Approach #13, for instance, refers to stakeholders as purchasers, consultants, experts and healthcare practitioners. Approach #14 describes stakeholders as patients, groups with professional expertise, organisations, healthcare professionals and practitioners, and in terms of the application context, a distinction is made between a core stakeholder group (doctors, pharmacists, nurses and microbiologists) and a second stakeholder group (emergency department consulting doctors, nurses and managers). The term stakeholders in Approach #15 encompasses research professors with specialist knowledge, funders, public health representatives, cultural and community expert consultants, and health promotion providers. In comparison, Approach #16 discusses stakeholder actors as including buyers, owners, operational services, designers and developers, care organisations, business managers and HI-U (health informatics and usability) specialists, and in terms of application context, distinguishes between intra-care and inter-care professional groups. Some of the stakeholder actors and community of practice members described in these four approaches can also be referred to as third-party stakeholders, although none of the articles explicitly use the term "third-party". Also related to stakeholder involvement, all four approaches make reference to participatory team involvements with academic institutions,

research groups and researchers. With regard to partnerships, Approach #15 highlights the importance of engaging in "a partnership-building process" that aims to create academic-community partnerships, where participation agreements stipulate equal roles of power, responsibilities and protection. Partnerships are also emphasised in Approach #13 which stresses the importance of developing close collaboration partnerships with programmers from digital development companies, and making use of flexible in-house software, specifically open-source software tools (such as LifeGuide) that can support intervention designers and developers with no experiencing in programming. In terms of team formalities, only two approaches (Approaches #15 and #16) discuss the need for actors and members to mutually and formally develop and sign team contract agreements.

On a different note, Approaches #13 and #14 use the terms health "intervention designers" and "intervention developers" to describe the multi- and interdisciplinary actors involved in the intervention development process. In comparison, Approaches #15 and #16 refer to "designers" and "developers" in light of technological expertise, with Approach #15 mentioning "app developers" and Approach #16 discussing "system designers" and "system developers". Concerningly, Approach #15 describes "graphic designers" as if they were app designers involved in the creation of user interfaces and design features for mHealth behaviour change intervention apps (and app prototypes). Such loose use of the term "graphic designers" to refer to app designers, is highly ambiguous and can be easily misinterpreted by other actors in the multi- and interdisciplinary team. In terms of multi- and interdisciplinary team management and facilitation, Approach #15 mentions a project management team, but does not discuss details, roles or logistics within this team, and in contrast, Approach #13 does not discuss team management or facilitation at all. Alternatively, Approach #14 discusses team facilitation responsibilities as being held by researchers, whereas Approach #15 assigns "community coordinators" as facilitators of focus group sessions and team activities. Overall, only one of the four approaches, specifically Approach #16, discusses the importance of a team lead facilitator in charge of managing, coordinating and facilitating the entire intervention development process. Approach #16 identifies these team lead boundary actors and knowledge brokers as health information and usability specialists, or "HI-U specialists" for short, and describes them as actors or "mediators" who are "fluent in the languages of both healthcare professionals and system engineers [designers and developers]". HI-U specialists facilitate all multi- and interdisciplinary thematic seminars (MdTSs), are responsible for managing coordination, cooperation and communication within the team, and are responsible for

developing extensive reports and documentation at the end of every stage of the development process. The heavy workload and extent of responsibilities assigned to HI-U specialists was however noted with concern, given the potential impacts to their personal health and wellbeing, and hence their ability to continue facilitating and mediating as a project progresses over time. Additionally, Approach #16 also made mention of a "user-centred design facilitator" as the intermediary between users and system (or app) designers and developers.

All four of the multi- and interdisciplinary approaches in the Partnership Perspective category discuss the active involvements and contributions of heterogeneous experts with specialist expertise, knowledge and skills, who all offer different perspectives of the shared intervention problem and solution space. In terms of mentioning specific actors with particular disciplinary expert knowledge and skills, Approach #13 identifies multi- and interdisciplinary team members to include: computer scientists; health behaviour change experts; and general practitioners. Approach #14 identifies team members to include: health behavioural scientists; clinicians; doctors; nurses; healthcare assistants; laboratorians; pharmacists; and microbiologists. Approach #15 identifies team members as including: app developers; graphic designers; cultural experts; nutrition experts; physical activity and exercise experts; health promotion providers; and public health researchers. Approach #16 identifies multi- and interdisciplinary team members to include: information communication and technology developers; healthcare professionals; doctors; clinicians; nurses; buyers; owners; organisation managers; operational service providers; system designers; system developers; user-centred designers; facilitators; care organisation consultants; HI-U specialist; usability designers; intra-care professional group members; and inter-care professional group members. With regard to target population (end user) representatives, as touched on earlier in this discussion, their active and direct involvement is stressed as a fundamental imperative in all four partnership orientated approaches. For example, Approach #15 is described by the authors as a "co-design" mHealth behaviour change intervention development process, Approach #14 emphasises a participatory design process that involves collaborative "co-design", "co-development" and "co-implementation" based on mutually formulated "co-definitions". As a final note, Approach #14 also suggests that active participatory involvement be driven by three key values, namely: having a say; mutual learning; and co-realisation.

#### 6.4.3.3 Perspectives, Underlying Theories, Models, Tools and Existing Approaches

In the Partnership Perspective category, three of the multi- and interdisciplinary approaches, namely Approaches #13, #14 and #15, adopt health promotion, health psychology and health behavioural sciences perspectives to behavioural change intervention development. In contrast, Approach #16 does not adopt any of these three perspectives, but instead adopts a clinical and medical healthcare service delivery perspective. Approach #14 similarly incorporates a primary healthcare management and service delivery perspective alongside a health behavioural sciences perspective. All four multi- and interdisciplinary approaches incorporate a socioecological approach. Approach #13 focuses specifically on gaining an "in-depth understanding of the psychosocial context of the people [that is, individuals] who will use the [health behavioural change] intervention" (Yardley, et al., 2015, p.11). Approach #14 generally focuses on the organisational socioecological level, although it also accounts for broader environmental factors existing in the structural, governmental, legislative and economic contexts, and how these influence individual health behaviour. Approach #15, similarly to Approach #13, is orientated towards the dual intra-inter(primary)personal socioecological levels of health promotion intervention development. Approach #16 describes the consideration of various social, organisational, business and cultural factors, although in the context of designing and developing health information systems, and not health behavioural change interventions. Within the Partnership Perspective category, active collaboration and participation is foundational to the four selected multi- and interdisciplinary approaches. All four approaches, therefore, adopt a participatory approach to development. Approach #13, for instance, emphasises the involvement of target (end user) population representatives "at every stage of [the] intervention development [process], from planning to feasibility testing and implementation" (Yardley, et al., 2015, p.1). Approach #14 describes participation as a "fundamental element of [health behavioural change] intervention design" (Carvalho, Jun and Mitchell, 2017, p.14). Approaches #15 and #16 likewise underscore the participatory approach and the integration of participatory methodologies or methods throughout both publication articles. In accordance with the discussions on the participatory approach and on participatory methodologies, three of the four multi- and interdisciplinary approaches explicitly and saliently integrate participatory design approaches and methods as the cornerstones of their development processes. Terminology used in relation to participatory design methods are co-definition, co-design, co-creation, co-development, co-production, co-evaluation and co-implementation.

Approach #15, for example, adapts Bratteteig, et al.'s (2012) "participatory co-design cycle" as an underlying method in their process for developing a tailored mHealth behaviour change intervention app for health lifestyle management and wellbeing. Approach #16, in a similar fashion, underpins their approach with a "collaborative design method" that emphasises cooperative multi- and interdisciplinary work. In comparison to the other three approaches, Approach #13 does not explicitly articulate the term "participatory design", and explicitly goes so far as to state that the "process is different from co-design with members of the target population" (Yardley, et al., 2015, p.7). However, Approach #13 is nevertheless in accordance with the participatory perspective as it stresses the employment of iterative in-depth qualitative research with participants (as target users) as central for "all stages of intervention development and evaluation" (Yardley, et al., 2015, p.8).

Partially associated with participatory approaches are the human- and user-centred design approaches. User-centred design is latently adopted in Approaches #14 and #15 as orientation is given towards gathering feedback and suggestions from participants during iterative design-test-refine cycles. Approach #16, in comparison, explicitly integrates user-centred design in its approach, particularly with its recommended appointment of a HI-U (health informatics and usability) specialist as the multi- and interdisciplinary team facilitator, who requires sound usability knowledge and expertise. Approach #13 does not incorporate human- or user-centred design approaches as they are traditionally understood within the information systems discipline, but instead flips these approaches around and applies them in the fields of health psychology and health behavioural sciences, proposing a novel "person-centred" and "person-based" approach to health behaviour change intervention development. The authors, do however explain that the Person-Based Approach can be "usefully incorporated within a multi- and interdisciplinary holistic human-centred design" approach, which suggests Approach #13's complementary use with information systems grounded perspectives. User interface design is mentioned in the papers on Approaches #14 and #16, and mHealth design features (which essentially characterise interface features) are discussed in Approach #15. Only one approach, namely Approach #13, touches on human-computer interaction design. None of the four approaches mention the design thinking perspective, although Approach #16 does discuss an innovative thinking perspective. User experience design is latently touched on in the article on Approach #15, although user experience design is central to Approach #13, but not from an information systems perspective. Approach #13 flips the interpretation of user experience design – similarly to how it flipped the human- and user-centred design perspectives – and

focuses on understanding and addressing users' perceptions and experiences of behaviour change techniques, intervention strategies (or components) and health behavioural interventions overall. This is a distinctly different view and interpretation of users' perceptions and experiences from the information systems and technology disciplines, which examine users' perceptions and experiences of user interface design features and mHealth design elements, and not interventions or intervention elements (strategies or components). In terms of technological perspectives, Approach #16 is the only approach that integrates a systems thinking approach (focusing specifically on health information systems), and centrally integrates a computer support cooperative work (CSCW) approach into its process. Approach #16 is also the only approach of the four that incorporates the soft systems methodology, the socio-technical perspective, and aspects of hardware and software architecture design and development. Keeping on the discussion of technology, only two of the four approaches (Approaches #13 and #15) adopt mHealth intervention and digital technology intervention perspectives. Approach #14, in sharp contrast to the other three multi- and interdisciplinary approaches, does not adopt any technological or digital perspectives. Only one approach, namely Approach #16, incorporates systems engineering and software engineering perspectives, and concentrates particularly on requirements engineering (a sub-function of systems engineering design). None of the four approaches employ UML (Unified Modelling Language) techniques. As far as context is concerned, two approaches (Approaches #13 and #15) are aimed at targeting healthy lifestyle behaviour modification and wellbeing management, and discuss physical activity behaviour change in particular. The other two approaches (Approaches #14 and #16) are not orientated towards the healthy lifestyle modification and wellbeing management context, and do not mention physical activity behaviour. None of the approaches discuss or incorporate perspectives from persuasive technology and/or persuasive systems design. Approach #13 discusses the power of "persuasion", but in relation to behaviour change techniques, intervention strategies (or components) or interventions overall, which is different to a technological and systems perspective and interpretation of "persuasion". Not one of the four approaches mentions or incorporates gamification. Moreover, none of the approaches consider or discuss the commercial smartphone app industry or the consumer app market. This is a notable limitation of the four approaches analysed in the Partnership Perspective category.

A theoretical basis underlies three of the multi- and interdisciplinary approaches, specifically Approaches #14, #15 and #16. Approach #14 reviews several theory-informed participatory

design methods and behaviour change frameworks to inform its development. Approach #15 fuses what they describe as "validated theoretical frameworks" with culturally-tailored theoretical models such as the Kaupapa Māori Co-Design Process. In comparison to the other three approaches, Approach #16 has a richer theoretical base, which is predominantly informed by the multi- and interdisciplinary thematic seminar (MdTS) method (grounded in CSCW), and also integrates activity theory, future workshops theory, the vision seminar process, and Checkland's soft systems methodology. Unlike the other three approaches, Approach #13 is not theory-based, and the authors note that the Person-Based Approach is "not intended to replace but to complement and enrich well-known 'theory-based' and 'evidence-based' approaches … [for] intervention development" (Yardley, et al., 2015, p.2). The approach, does however, employ theory-based models and frameworks during the development process. On another note, with regard to individual and interpersonal theories, only one approach of the four (Approach #13) briefly mentions self-determination theory (SDT), self-efficacy theory (SET), and theory of planned behaviour (TPB). The other three do not mention or discuss individual and interpersonal psychology theories. Furthermore, none of the four approaches acknowledge or incorporate theory on just-in-time adaptive interventions, which has shown to be valuable when developing effective mHealth behaviour change app interventions, particularly in the contexts of physical activity and sedentary behaviour (Muller, Blandford and Yardley, 2017; Nahum-Shani, et al., 2018; Direito, et al., 2019).

The employment and use of theory-informed and evidence-based (health) models and tools are invaluable when developing mHealth behaviour change app interventions. Three of the four approaches, specifically Approaches #13, #14 and #15 utilise two coding taxonomies: the CALO-RE Taxonomy and the BCTT v1. One approach (Approach #14) employs a taxonomy of development, namely the Taxonomy of Behaviour Change Methods (TBCM), which is extracted from the Intervention Mapping protocol (Approach #1). Two approaches (Approaches #14 and #15) make use of the Theoretical Domains Framework (TDF). The Behaviour Change Wheel (BCW) and the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model) forms an integral part of the development of Approach #14, although neither the BCW nor the COM-B Model are amalgamated into the other three approaches. Approach #13 does, however, acknowledge BCW, but does not use or incorporate it in its process. None of the approaches mention the PRECEDE-PROCEED Model. Similarly to the BCW, Approach #13 acknowledges the Ritterband Model, but does not use or incorporate it. Approach #14 is the only approach that makes use of the APEASE Criteria (Affordability,

Practicability, Effectiveness, Acceptability, Side Effects and Equity), while the other three fail to acknowledge or mention it. Approach #16 does not refer to or use any of the (health) methods and tools discussed here. The Health Information Technology Usability Evaluation Model (Health-ITUEM) is not recognised in any of the papers. None of the multi- and interdisciplinary approaches in the Partnership Perspective category mention or incorporate the Functional Triad, Fogg's Behavioural Model (FBM) or the Persuasive Systems Design Model (PSDM). Given the culturally-tailored context of mHealth behaviour change intervention focus, Approach #15 employs and incorporates three cultural-specific theoretical models, namely the Te Whare Tapa Whā (Model for Māori Health); the Te Pae Mahutonga (Model for Māori Health Promotion); and the Fonofale (Model for Pasifika Health). None of the other three approaches employ culturally-sensitive models.

Value can come from incorporating and adapting existing multi- and interdisciplinary approaches to inform the development of a new approach. Approaches #13 integrates the Intervention Mapping (IM) protocol (Approach #1) into its person-based digital health behaviour change intervention development process. Dissimilarly, Approach #13 makes reference to Approaches #2, #3 and #7, but does not incorporate any of them into the Person-Based Approach. Approach #14, unlike Approach #13, does not refer to or use Approach #1, but it lies latently behind the Taxonomy of Behaviour Change Methods (TBCM). Furthermore, Approach #14 recognises and briefly mentions Approaches #3 and #13, but neither of them are reviewed to inform the development of Approach #14's process. In comparison to Approaches #13 and #14, Approaches #15 and #16 do not reference or draw from any existing multi- and interdisciplinary approaches.

#### 6.4.3.4 Nature of Approaches and Process Steps and Activities

*Nature of the Approaches*

Three of the multi- and interdisciplinary approaches in the Partnership Perspective category, namely Approaches #13, #15 and #16, are iterative and cyclical in nature. All four approaches possess participatory and collaborative characteristics. Moreover, all four are cumulative in nature, albeit in different ways. Approach #13, for instance, is cumulative in that the results and findings generated through in-depth qualitative research continues to add up over time, gradually developing a richer and more informed understanding of the psychosocial contexts and user perspectives of people who will use a given digital health behaviour change

intervention. In comparison, Approach #14 demonstrates cumulative characteristics in its series of workshops, which over time, aim to develop co-definitions and mutual shared understandings of the intersecting problem and solution spaces, which subsequently inform the co-development and co-implementation stages. Approach #16 is similar to Approach #14 in that the findings generated through a series of several multi- and interdisciplinary thematic seminars gradually contributes to a growing understanding of a given health information system's development. In terms of theory and evidence, Approach #15 is the only approach where the authors stipulate a theory-based and evidence-based process. Approaches #13, #14 and #16, in comparison, exhibit theory-based and evidence-based qualities, although latently, and not explicitly. Approach #14, for instance, frequently refers to the "evidence conundrum" and stresses the need for more qualitative, and not only quantitative, evidence. Approach #16, for example, is informed by theory-based multi- and interdisciplinary thematic seminar and seminar-related methods. Approach #13, in comparison to the other three, discusses theory and evidence the least, although it does acknowledge the value in referring to and drawing from literary theory(ies) and evidence in the first component (the intervention planning stage). Besides that, Approach #13 tends to suggest that the Person-Based Approach be used in conjunction with and complementary to other theory-based and evidence-based approaches. Moving on from theory and evidence, three approaches can be described as systematic, although this is an explicitly mentioned in Approaches #13 and #15, and lies latently in Approach #14. Dissimilarly, Approach #16 is not systematic, with the authors explicitly explaining that the multi- and interdisciplinary thematic seminars need "not necessarily [be] held in consecutive order" (Scandurra, Hägglund and Koch, 2008a, p.559). Approaches #13, #15 and #16 are non-linear in nature, although there are aspects of linearity within Approach #15 (such as steps 5.1 to 5.4). Approach #14, disparately, demonstrates linearity, progressing from co-definition (stage one) to co-development (stage two) to co-implementation (stage three). On a final note with regard to nature and characteristics, Approach #16 is the only approach that is described as "reflective", and Approach #14 is the only approach where the authors explicitly describe the process as "practical". Although Approaches #13 and #16 do latently exhibit practical characteristics and practical considerations in both of their articles' discussions.

### *Process Steps and Activities*

All four of the multi- and interdisciplinary approaches in the Partnership Perspective category provide a series of steps (also referred to as stages, phases or components) that constitute prescribed processes for guiding intervention designers and developers in developing participatory and collaborative health behavioural change interventions. The various process steps (stages, phases or components) for each partnership approach is provided Table Appendix I.3. For each of the four processes, Table C in Appendix H provides detailed descriptions, sub-steps and activities for each step, as well as the methods, tools and artefacts used and/or produced at each step.

*Table Appendix I.3: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Partnership Perspective Category [Researcher's own construction]*

| Approach #13 | Approach #14 | Approach #15 | Approach #16 |
|---|---|---|---|
| Component 1:<br>Intervention Planning | Stage 1:<br>Co-Definition:<br>Understand the Behaviour | Step 1:<br>Opportunity Identification and Partnership Building | **Holistic Perspective** |
| Component 2:<br>Intervention Optimisation | Stage 2:<br>Co-Development:<br>Identify Intervention Options | Step 2:<br>Elucidation of Needs and Desires and Knowledge Generation | Seminar Theme 1:<br>Project Start-Up – Introduction |
| Component 3:<br>Intervention Implementation | Stage 3:<br>Co-Implementation:<br>Identify Content and Implementation Options | Step 3:<br>Description of mHealth Intervention Requirements | Seminar Theme 2:<br>Current Work Situation |
| | | Step 4:<br>Envisaging the mHealth Intervention Tool | Seminar Theme 3:<br>Organisation in Practice |
| | | Step 5:<br>Iterative mHealth Intervention Development and Prototype Testing | Seminar Theme 4:<br>Information and Community Handling |
| | | Step 5.1:<br>Identify Key Content Modules | Seminar Theme 5:<br>Technical Workshop |
| | | Step 5.2:<br>Identify Relevant Determinants of Behaviour Change | Seminar Theme 6:<br>Future Work Perspective |
| | | Step 5.3:<br>Select Appropriate BCTs | **Detailed Perspective** |
| | | Step 5.4:<br>Incorporate the BCTs in the mHealth Intervention | Seminar Theme 7:<br>Current Work Scenarios – Intra-Care Professional |
| | | Step 6:<br>mHealth Intervention Prototype Evaluation | Seminar Theme 8:<br>Current Work Scenarios – Inter-Care Professional |
| | | | Seminar Theme 9:<br>Detailed Analysis of Information Needs |
| | | | Seminar Theme 10:<br>Future Work Scenarios – Intra-Care Professional |

| | | | |
|---|---|---|---|
| | | | Seminar Theme 11: Future Work Scenarios – Inter-Care Professional |
| | | | Seminar Theme 12: Visualisation of Future Work Scenarios |

### *Step 1*

A comparative review of the four multi- and interdisciplinary approaches in the Partnership Perspective category reveals three approaches, namely Approaches #14, #15 and #16, to explicitly discuss steps and activities pertaining to the formation and formalisation of a multi- and interdisciplinary team at the preliminary onset of a health intervention development process. These multi- and interdisciplinary team related activities fall under *Step 1* of the collaborative and partnership process. All three approaches (Approaches #14, #15 and #16) discuss forming a multi- and interdisciplinary team that involves a heterogeneity of relevant parties and perspectives. Approach #14 discusses the importance of performing preliminary team activities and processes to help participating team members work together in establishing a shared common ground, which in turn lays the groundwork for all future collaborative and cooperative teamwork. Similar to Approach #14, Approach #15 also stresses the importance of putting effort into establishing and formalising a multi- and interdisciplinary team and strong partnerships prior to initiating an mHealth behaviour change app intervention development process. Approach #15 defines this stage as Step 1 "Opportunity Identification and Partnership Building", in which the first aim is to identify an opportunity for a potential partnership and an intervention need, and the second aim is to establish and build a partnership between academic researchers and community members. To achieve these aims, Approach #15 outlines a few activities, including: assembling a variety of suitable partners from both the academic and community sides; conducting face-to-face project team and partnership meetings to develop group cohesion; formally defining a partnership agreement; establishing a team culture and relationship/partnership values and principles; defining a project culture and project values; stipulating the project funding; and creating various formal agreements regarding the partnership (incorporating trust, respect, empathy and empowerment), team communications, meeting structures, and conflict and tension resolution processes. Some of these activities are mirrored in Approach #16's "Project Start-Up and Introduction" first stage, as part of Thematic Seminar Theme 1. Activities suggested by Approach #16 at this stage revolve around get-together activities concerning: the multi- and interdisciplinary team members' roles,

responsibilities, work practices and work descriptions; the project team contract; the project model; the project rules, regulations and guidelines; the project aims; and the initial project ideas.

Approach #16 offers additional contributions to fostering multi- and interdisciplinary collaborative teamwork. The core elements imbuing Approach #16's process are the multi- and interdisciplinary thematic seminar and cooperative work methods. Approach #16 defines an initial "Pre-Seminary Work" phase, which involves performing contextual inquiries to understand the multi- and interdisciplinary team members' diversity of specialist knowledge and expertise, and also aims to capture the valuable tacit knowledge and insights they can offer the team. Approach #16 highlights how team members (from a particular discipline) tend to focus predominantly on their own roles, responsibilities and activities during the development process, and generally have little to no insight into the knowledge contributions and work practices of other team members (from unalike disciplines). Lack of shared understanding and insight into each other's perspectives results in a "fragmented picture" of what the collaborative work process involves (Scandurra, Hägglund and Koch, 2008). Therefore, running a series of multi- and interdisciplinary thematic seminars is proposed as a method for supporting and facilitating collaborative and cooperative teamwork throughout the digital health intervention development process. Furthermore, Approach #16 presents and recommends that a Health Informatics and Usability (HI-U) specialist assume the role as lead facilitator when conducting the series of multi- and interdisciplinary thematic seminars. HI-U specialists essentially have a grasp and understanding of the heterogeneity of knowledge contributions and expertise offered by participating team members, and hence are able to support and facilitate cooperative and collaborative work practices through effective means of inter-disciplinary translation and communication. In terms of key process activities, HI-U specialists are presumed responsible for creating and disseminating documentation associated with both the multi- and interdisciplinary team (including contracts, partnership agreements, rules, guidelines, et cetera) and the project (such as project management and project model documentation). To further aid multi- and interdisciplinary team work, Approaches #14, #15 and #16 all discuss the value in utilising computer- and digitally-mediated technologies and online platforms as mediums for supporting partnership and team communications and information exchanges throughout the mHealth behaviour change app intervention development process.

Once a multi- and interdisciplinary team is established and formalised, team members can commence the digital health intervention development process by continuing with the remainder of activities comprised in *Step 1*. At this stage of the process, the key essence of the main aim shared by all four partnership approaches is to gain an understanding of the problem space and target population group. As early groundwork, Approach #13 recommends scoping the existing knowledge base by reviewing literature, systematic reviews, meta-analyses and findings from published (quantitative and qualitative) empirical studies; all of which should be relevant to the health problem and target audience. Based on these reviews, Approach #13 draws from Approach #1 (Intervention Mapping) in suggesting that the multi- and interdisciplinary team work together in creating a Logic Model of the Problem (diagram), outlining the key causal relationships between the health problem, the at-risk health behavioural factors, and the associated evidence-based behavioural determinants. Approaches #14, #15 and #16 do not acknowledge or discuss creating a Logic Model of the Problem, which is a limitation considering it provides the team with a precursory guideline and direction to follow when navigating the problem space. Nonetheless, all four partnership approaches specify gaining an understanding of the problem space by conducting qualitative research with representatives of the target population group. In the Intervention Planning stage (in Component 1), Approach #13 describes Step 1.1 as essentially aiming to "Conduct Qualitative Research". The principal intention is to conduct in-depth and exploratory qualitative research with target representatives as a means to better understand and accommodate the psychosocial contexts and user experiences of people who will ultimately be using the digital health behavioural change intervention. Approach #13 recommends employing qualitative methods such as interviews and focus groups to elicit the target population group's attitudes, beliefs, perceptions, experiences, feelings, needs, understandings, contexts and situations with respect to their demographic characteristics (such as sex, gender, culture, health literacy, socioeconomic status, (dis)abilities, previous experiences). Drawing out key barriers, facilitators and contextual issues pertinent to the target behaviour and target population can also be informative. In addition, and importantly, Approach #13 emphasises using in-depth qualitative methods and open-ended questions to ascertain and identify intervention components (strategies and features) that are most salient, engaging, persuasive, acceptable, feasible and preferred by the target population group. According to Approach #13 and Morrison, et al. (2018), some example questions include: "What are the target users' lives like?", "What do they value?", "What are their prior experiences of engaging with the targeted health behaviour?", "What concerns do they have?", "What do they perceive as

advantages/disadvantages to performing the target behaviour?", and "How do they feel about making these behavioural changes?". Notably though, Approach #13 repeatedly stresses that these psychosocial exploratory investigations should not pertain to the digital technology platform, but instead focus specifically on the health behavioural change intervention itself. According to Approach #13, conducting in-depth qualitative research with target population representatives from the commencement of the project can reveal unexpected, alternate, and at times, conflicting findings which may be distinct from, or even contradict, existing theoretical knowledge and empirical reportings. Critical thought trials stimulated (in the researcher's mind) in response to reviewing and analysing Step 1.1 in Approach #13, judges an understanding of the problem space as determined through a combined review of the existing knowledge base accompanied by in-depth qualitative and exploratory research; thereby striking a somewhat balance between a predominant inductive, and supplementary deductive, sense-making process.

Approaches #14, #15 and #16 possess inherently similar characteristics in that the multi- and interdisciplinary team's understanding of the problem space is ascertained through conducting primary qualitative studies alongside reviews of the existing knowledge base. To better understand the problem space, Approach #14's Stage 1 suggests the team create a "Co-Definition" (that is, a shared understanding) utilising methods and tools from both the health sciences and participatory design arenas. On the one side, from a health sciences perspective, tools such as the Behaviour Change Wheel (BCW) can be used to identify and understand: what the health behaviour is; who performs it; whom it is performed with; where it is performed; and how frequently it occurs. On the other side, from a participatory design perspective, a shared understanding of the problem space can be supported and facilitated using methods and techniques including: user interviews; focus groups; user forums; card sorting; user journeys; story-telling; thematic network mapping; and 2D mapping. Workshops, however, accompanied by group and reflective discussions, are the predominant recommended participatory techniques for supporting collaborative efforts when creating a "co-definition" and mutual understanding of the problem space. Thematic network and 2D mapping techniques are valuable for creating visual representations (diagrams) of the problem space that factor in the complexity of problem-related variables and the participating team members' multiple perspectives. Creating a shared list of behavioural challenges – which addresses the BCW's questions concerning what, who, with whom, where and how frequently – can also be used by team members to review, discuss, organise, prioritise and revise details applicable to the

problem space and visual representations. In comparison to Approach #14, Approach #15's Step 2 "Elucidation of Users' Needs and Desires and Knowledge Generation" emphasises the use of focus groups and discussion methods (such as story-telling and metaphors) to establish an understanding of the problem space and to elicit users' thoughts, needs, ideas, desires and opinions in relation to the problem at hand. Approach #15 further suggests employing data collection tools such as photographs, audio recordings, visual recordings, reflection worksheets, white boards and paper (written notes) to capture users' input during the focus group discussions. To elicit users' input, Approach #15 recommends asking questions regarding users' hopes and dreams, lifestyle behaviour interests, preferences, barriers and facilitators, as well as their attitudes towards and thoughts concerning smartphone devices and mHealth app technologies. These questions proposed by Approach #15 mirror many of the questions suggested by Approach #13. In addition, further understanding of the problem space can be gathered through running thematic seminar sessions with participant representatives of the target population group, as put forward by Approach #16. Thematic seminar themes 2 ("Current Work Situation"), 3 ("Organisation in Practice") and 4 ("Information and Community Handling") discussed in Approach #16 are informational in that the activities mentioned generally pertain to gathering a deeper and better understanding of the "current" state of affairs, that is, the problem space. Some additional methods and tools that Approach #16 mentions which may be helpful include: contextual inquiries; user analyses; task analyses; environmental (or socioecological) analyses; social and cultural analyses; and information flow and workflow analyses. Another noteworthy contribution by Approach #16 is the assignment of work responsibilities to HI-U specialists, who are tasked with consolidating the results and analysing the findings from each thematic seminar into concentrated, mutually understandable outputs for distribution amongst the whole multi- and interdisciplinary team. These mutually intelligible outputs are instrumental for ensuring that the multi- and interdisciplinary (heterogeneous) team members are on the same page at every stage of the digital health intervention development process, particularly in terms of a "co-definition" of the problem space.

At the crux, a comparison between Approaches #13, #14, #15 and #16 reveal similarities in employing qualitative research methods, alongside reviews of the existing knowledge base, as a participatory and partnership approach to better inform the multi- and interdisciplinary team's understanding of the problem space and the target population group's needs, characteristics, preferences and psychosocial contexts.

### *Step 2*

In moving from *Step 1* to *Step 2*, a comparative overview of the four multi- and interdisciplinary approaches in the Partnership Perspective category reveals a chief intention that aims to progress from a shared understanding of the problem space, towards a shared and common understanding of the joint solution space. This shared solution space parallels the activities involved in the conceptualisation of a design solution. To mobilise this transition, Approach #13's Intervention Planning stage (in Component 1) outlines Step 1.2 which aims to "Create Guiding Principles". These guiding principles are informed by outputs of activities performed in *Step 1*, specifically the findings from the scoping review of literature and empirical studies, and the findings elicited during primary qualitative research with target users. According to Approach #13, "Guiding Principles" aim to coherently focus the team's attention by highlighting the distinctive and particular qualities of the digital health behavioural intervention. To elaborate, guiding principles support multi- and interdisciplinary team members' collaborations by providing a mutually intelligible succinct and accessible summary of the intervention plan, which can be used as a shared tool for facilitating and enhancing communication across the different disciplines (Morrison, et al., 2018). In other words, their purpose is to provide the team with a common reference point that can be consulted at all stages of the intervention development process. Guiding principles consists of two elements: (1) a specification of the intervention's core design objectives; and (2) a specification of the intervention's key features, which support the achievement of the core design objectives. For the first element, the design objectives specify what the health behavioural intervention must do in order to address the needs of the target users, and how users' engagement with the intervention will be enhanced. Examples of intervention design objectives include: "to help people maintain their physical activity independently"; "to help people maintain physical activity in the long term"; and "to provide a positive, useful and rewarding experience for users". For the second element, the key intervention features specify how the design objectives may be achieved in practice. In describing the key features, the guiding principles need to succinctly capture the characteristics of the intervention that intend to optimise its engagement, acceptability, feasibility, persuasiveness and henceforth, its effectiveness. Key features can be described in terms of the BCTs, and also in broader aspects of the intervention that suggest how particular BCTs may be implemented to ensure they are optimally engaging and persuasive (for example, with respect to tone, language, mode of delivery, structure, and intended frequency of use). Two examples of key features are: "to build users' autonomous

motivation, self-regulation skills and confidence to become their own physical activity coach"; and "to focus on creating sustainable lifestyle physical activity habits rather than relying on supervised facility-based activities". Additional examples of design objectives and key intervention features, and steps illustrating the process for creating guiding principles, can be referred to in Approach #13 (Yardley, et al., 2015, p.7, 8 and 10).

In a nutshell, in terms of *Step 2*, guiding principles help coherently focus the conceptualisation of the design solution, and because they are grounded in a deep understanding of the target population group's psychosocial context, they are useful for guiding how theory-informed and evidence-based intervention content and techniques are delivered and communicated. However, while acknowledging their usefulness, it is important to note that guiding principles are not intended to replace the extensive intervention planning documentation that outlines how the theoretical model and the theory-based methods (change mechanisms) map to practical intervention techniques (BCTs), but instead intends to provide intervention designers and developers with a common reference point and a succinctly focused summary for easy referral and recall. Overall, Approach #13's guiding principles offers a valuable tool that can be utilised in conjunction with, and complementary to, other theory-based intervention planning techniques (such as BCW behavioural analyses and IM logic models).

In *Step 2*, other tools and techniques that can be employed and applied when conceptualising the design solution are discussed in Approaches #14, #15 and #16. Stage 2 in Approach #15, for instance, suggests the team co-create (that is, collaboratively create) a "Shared Vision" of the solution space by explicitly defining a common and mutual understanding of the conceptual design solution. Step 3 in Approach #15 stipulates creating a "Description of the mHealth Intervention Requirements", which aims to identify and define the main requirements of a particular mHealth behaviour change app intervention. After which, Step 4 in Approach #15 specifies that the team "Envisage the mHealth Intervention Tool". This envisagement essentially aims to explore possible design solutions for an mHealth behaviour change app intervention that represents and aligns with the requirements, needs and desires of the target population group. For both Steps 3 and 4, Approach #15 recommends conducting focus groups with representatives of the target population as a means to elicit the main requirements of the mHealth app, and explore design ideas and possible solution envisagements that are collectivist and conceptual (rather than concretely material) in nature. Furthermore, in referring back to utilising Approach #13's guiding principles in conjunction with other intervention planning

tools, Approach #14's Stage 2 aims to "Co-Develop" a health behavioural intervention by "Identifying Intervention Options" from both the health sciences and participatory design perspectives. From a health sciences perspective, the design solution can be conceptualised by employing the BCW and COM-B Model as tools for identifying appropriate intervention functions and policy categories associated with specific determinants of the targeted health behaviour. From a participatory design perspective, the design solution's conceptualisation can be explored and investigated by ideating alternative and innovative ways to respond to the defined problem space, by considering various other features, elements and processes. Examples of some partnership and participatory techniques that Approach #14 mentions as useful for supporting the collaborative design solution process include: brainstorming; 2D prototyping; 3D prototyping; insight cards; idea generation cards; scenarios; and personas. Similarly, with regard to conceptual ideation and design methods, Approach #15 discusses employing a variety of creative and expressive techniques. Examples of creative materials include colourful moulding putty, shapes, fluffy pom-poms, beads, ribbons, picture and paper cut-outs, et cetera. These creative materials and expressive techniques are used as participatory design tools for tangibly eliciting target users' ideas and preferences with respect to features and functionalities of mHealth apps. To further elicit conceptual design ideas, Approach #15 proposes running a "bus stop activity" with participant representatives of the target population. In a focus group or workshop setting, the bus stop activity requires participant users provide feedback and opinions on features and functionalities of existing mHealth apps that target the same, or similar, health behaviour(s) and population group(s).

Similar to the shared problem space, Approach #14 emphasises workshops as a predominant participatory design technique for supporting collaborative efforts towards co-creating and co-designing a "future vision" for the shared solution space. Approach #14 suggests running a series of workshops that target different objectives. Initial workshops target idea generation and idea prioritisation, and subsequent workshops target the health behavioural change intervention's design conceptualisation and planning. Insights gathered from these workshops can be used to inform the design solution space. Workshops covering idea prioritisation, for instance, recommends team members participate in exercises that uncover and organise similarities and differences in their top proposed design solution priorities (that is, similarities and differences that arise given their different disciplinary perspectives). Another valuable contribution suggested by Approach #14 is a priority strategy action plan, which helps team members coordinate and cooperate around heterogeneous work practices by embracing the

different complementary roles and involvements, and the different strengths, knowledge and expertise offered by each team member with respect to each prioritised design solution. Moreover, Approach #14 discusses running workshops with experts as another means of gathering potential design ideas and conceptual solution suggestions. Approach #14 also mentions co-developing a Logic Model of Change (diagram) (discussed in Approach #1) to illustratively depict the intended intervention effect pathways of a health behavioural change intervention. In this respect, Approach #14 mirrors Approaches #1 and #5 (from the Health Sciences category) in that the Logic Model of Change is used as a participatory and collaborative diagram to help inform the team's ideations and conceptualisations of the health behavioural intervention's design solution.

In terms of the details pertaining to the conceptual design solution, only one approach of the four multi- and interdisciplinary approaches in the Partnership Perspective category, namely Approach #15, discusses the importance of reviewing, identifying and selecting theory- and evidence-based intervention strategies when conceptualising the mHealth app's design solution. Approach #15 specifies these activities under three of the four sub-steps in Step 5. In these three sub-steps, Approach #15 emphasises the role of an academic-community partnership between researchers and participant representatives of the target population group. In Step 5.1 "Identify Key Content Modules", the academic team summarises the main health and wellbeing themes and content modules highlighted by the target representatives from earlier focus group discussions (in Steps 2, 3 and 4). Examples of two key themes and content modules are physical activity and health eating. The summarised key themes and content modules are then shared with target representatives in a subsequent focus group session, during which participants are asked to rank and prioritise the content modules on a scale of one to five (ranging from least to most important). Thereafter, Step 5.2 specifies that the academic research team "Identify Relevant Determinants of Behaviour Change". Based on the earlier focus group discussions (elicited during Steps 2, 3 and 4), the academic team identifies and selects theory- and evidence-based determinants and change mechanisms (theory-based methods) that enable and impede changes in the target group's relevant health behaviours. Approach #15 suggests comparing and identifying similarities in the determinants and mechanisms between the findings from the focus group discussions and the Theoretical Domains Framework (TDF). According to Approach #15, examples of theory- and evidence-based determinants relevant to mHealth physical activity behaviour change apps include: empowerment; self-monitoring; social support; knowledge; and goal setting. Following Step 5.2, Step 5.3 specifies that the

academic team "Select Appropriate Behaviour Change Techniques (BCTs)" by matching the design ideas, priorities and determinants findings from the focus groups in the co-design phase with evidence-based BCTs. To support this matching and selection activity, Approach #15 recommends utilising the CALO-RE and BCT v1 Taxonomies. Furthermore, Approach #15 suggests creating a table that presents the links between quoted examples of the co-design findings (extracted from the focus groups), the determinants, and the BCTs. Examples of theory- and evidence-based BCTs identified by Approach #15 as relevant to mHealth physical activity apps include: provide general encouragement; prompt self-monitoring; plan social support; provide information on physical activity behaviour; and prompt goal setting; all of which correspond directly and respectively to the example determinants identified in Step 5.2. In short, Approach #15 is the only partnership approach that provides intervention designers and developers with guidelines for planning and detailing the conceptual and theoretical design of the mHealth behaviour change app; covering the identification and selection of key content modules, relevant determinants and appropriate BCTs in relation to the target behaviour and target population. Notably, although Approach #14 mentions using the BCW and COM-B Model in Stage 2 to develop a "Shared Vision", it fails to offer explicit guidelines detailed to the level as provided by Approach #15.

Overall, with regard to *Step 2* and the shared solution space, a comparative review and analysis of Approaches #13, #14, #15 and #16 reveals a similar fundamental aim. That is, to employ qualitative and participatory design methods as a partnership approach to generating ideas and conceptualising design solutions that address the defined health behavioural intervention problem space. These co-design and co-creation participatory methods essentially aim to actively engage and collaborate with target population representatives to inform a richer conceptualisation of the design solution.

### *Step 3*

Once a design solution has been conceptualised in *Step 2*, the multi- and interdisciplinary team transitions to *Step 3*, where attention shifts towards designing, developing and prototyping a more concrete materialisation of the health behavioural change intervention. Notably, in terms of concrete realisation, Approaches #13 and #15 focus on performing iterative design-develop-test-refine cycles for health behavioural change interventions delivered via digital technology platforms, specifically smartphone apps. In contrast, Approaches #14 and #16 focus on generic primary care non-digital health interventions and health information systems, respectively. In

terms of Approach #13's Component 2 "Intervention Optimisation", effort is first given to developing an initial concrete prototype based on the conceptual design from *Step 2*. The main intention behind this component is to run a series of iterative intervention optimisation studies by conducting qualitative research with participant representatives of the target population group. The reason for conducting cyclical qualitative studies is to generate users' feedback on the prototypes with regard to their user experiences, perceptions, opinions and preferences concerning the acceptability, usefulness, feasibility, persuasiveness and adherence of the intervention and its component elements (BCTs). Insights gained from users' feedback then informs further iterative refinements and modifications to the intervention and its components (thus describing "intervention optimisation"), which accordingly also informs and needs to align with refinements and modifications to the guiding principles (created in *Step 2*). According to Approach #13, a qualitative study method that will help at the earlier prototype testing stage is the observational think-aloud technique, and at the later prototype testing stage, piloted longitudinal studies (six to eighteen months in duration). Markedly, in critically analysing and comparing the multi- and interdisciplinary partnership approaches, cognitive thought trials and judgement-making processing facilitates identifying a misinformed synonymous reference to prototyping and piloting as the same (or similar) activity. Notably though, there is a distinction between prototyping and piloting (Mummah, et al., 2016; Stavric, Saywell and Kayes, 2019). The earlier intervention optimisation cycles proposed by Approach #13 are orientated towards iterative prototype design-test-refine cycles; whereas the later intervention optimisation cycles are focused on piloting the intervention. A distinction between the two is demonstrated by several studies on digital health behavioural change interventions, which have employed the person-based approach (Approach #13) to guide prototype testing activities specifically, and not pilot testing activities (Davies, 2015; Rodrigues, et al., 2017; Bradbury, et al., 2019; Stavric, Saywell and Kayes, 2019). Further cognitive thought trials and judgement-making processing facilitates identifying a corresponding parallel between Approach #13's iterative qualitative prototyping approach and prototyping approaches discussed in the Health Sciences and Information Systems and Technology Perspective categories. However, a principal distinction between these approaches is that Approach #13 focuses solely on optimising the persuasiveness, feasibility and acceptability of the intervention and its constituting components (BCTs). This represents an exclusive health sciences and health psychology perspective, at the expense of the information systems and technology perspective. Approach #13 therefore fails to consider and investigate users' feedback on their experience, engagement and acceptance of the digital platform. In sharp contrast to Approach

#13, the prototype testing stages in the information systems and technology approaches stress the importance of gathering users' feedback on the translation, operationalisation, instantiation and concrete material design of BCTs as technological features and functionalities in a given digital platform. Unlike Approach #13, information systems and technology approaches seldom focus solely on the digital perspective at the expense of the health sciences perspective, and generally consider and account for both viewpoints. In comparison to other digital and mHealth development processes, the lack of attention to the selected platform (mode) of intervention delivery is a notable weakness of Approach #13, especially considering the distinctive characteristics, capabilities and limitations of the smartphone app platform that should be accounted for when designing and developing a health behaviour change intervention.

Approach #15, in comparison to Approach #13, acknowledges and accounts for the information systems perspective by testing and gathering users' feedback with respect to how BCTs are translated and operationalised into concrete material mHealth app design features. In Step 5.4 of Approach #15, attention is given to "Incorporating the BCTs in the mHealth Intervention" by consulting and collaborating with participant representatives of the target population group as well as smartphone app designers and developers. Approach #15 specifies running a series of design-develop-test-refine prototype testing cycles as a means to iteratively improve the concrete and material design of an mHealth behaviour change app. According to Approach #15, prototype testing is generally performed over a three-month period. Approach #15 also suggests creating a table that outlines how the examples of participant co-design findings correspond to determinants, selected BCTs, and operationalised BCTs as design features. An example of this table particularised to the context of an mHealth physical activity app is provided in Approach #15 (Verbiest, et al., 2018, p.9-10). Moreover, during the prototyping iteration process in Step 5.2, Approach #15 suggests testing and generating users' feedback by paying close attention to the characteristics, preferences, culture and capabilities of the target population group.

Unlike Approaches #13 and #15 which propose digital health behavioural change intervention development processes, Approach #14 and #16 are generic and non-digital in nature. Nevertheless, Approach #14 provides a contribution to *Step 3* by recommending that both the health sciences perspective and participatory design perspective be recognised, and that both sides cooperate and collaborate together, when conducting prototype testing on a health

behavioural change intervention. In addition, Approach #14 mentions a few participatory design methods that may be useful during this stage of the process, including usability testing, heuristic evaluation, role-playing, and user experience design testing. Be this as it may, Approach #14 does, however, fail to provide intervention designers and developers with sufficient details or guidance for collaboratively carrying out prototype testing on a health behavioural change intervention. On another note, out of the four partnership approaches, Approach #16 is the only approach that suggests running a thematic seminar and workshop orientated towards educating and showing participant representatives of the target population group the value in understanding technological hardware and software, and human-computer and interaction design related considerations. Specified as "Seminar Theme 5" in Approach #16, technical workshops can provide a space for discussions concerning digital design features and functionalities, usability, user experience design, current technological advancements (and the pros, cons, opportunities and limitations thereof). According to Approach #16, experts with various relevant digital technology specialist knowledge can present at the multi- and interdisciplinary seminar and workshop, and HI-U specialists can be responsible for facilitating the process and discussions. Furthermore, along with the technical seminars, Approach #16 also suggests the multi- and interdisciplinary team make use of various creative and practical methods and techniques when performing design-test-refine prototyping sessions with and gathering feedback from participant user representatives. Some examples of methods and techniques include creating and refining: use case models; use case narratives; detailed scenario descriptions; user workflows; interaction workflows; information flows; representational analyses; and role-play scenarios. Despite the suggestions for running a technical seminar and workshop with participants, and using various prototype testing methods and techniques, Approach #16 is somewhat similar to Approach #14 in that it does not offer multi- and interdisciplinary teams detailed guidance for conducting iterative design-develop-test-refine cycles that can help improve the design features and functionalities of digital health interventions and mHealth behaviour change apps.

On an alternate and final note, Approach #13 is the only partnership approach that discusses running pilot testing cycles on the digital (or mHealth app) behaviour change intervention; whereas the other three partnership approaches do not include or discuss a pilot testing stage in their multi- and interdisciplinary processes. Pilot testing is specifically incorporated in Approach #13's Component 2 "Intervention Optimisation" which focuses on utilising in-depth qualitative research methods to pilot test and further improve (that is, "optimise") the digital

health behavioural change intervention with a group (or groups) of participant target users. However, as already pointed out in the critical discussion earlier, Approach #13 does not explicitly distinguish between prototyping and pilot testing, yet published studies that have employed the person-based approach have often noted and described the distinctions. Davies (2015, p.31), for instance, uses Approach #13 to guide the iterative design and development of a digital website-based health behaviour change intervention prototype for alcohol usage, but explicitly distinguishes performing the prototyping stage "prior to its [the intervention's] implementation in a pilot trial". Another recent study that applies the person-based approach (Approach #13) and clearly demarcates conducting prototype testing before pilot testing is Stavric, Saywell and Kayes (2019). Using two qualitative methods suggested by Approach #13, specifically focus groups and think-aloud sessions, Stavric, Saywell and Kayes (2019) describe first performing a series of iterative design and refine cycles to develop a self-management website-based exercise intervention prototype, before progressing to subsequent "future work" were the prototype will be pilot trial tested over a twelve-week period. In addition to these two studies (Davies, 2015; Stavric, Saywell and Kayes, 2019), a few other studies that employed the person-based approach (Approach #13) also explicitly demarked the iterative prototype testing stage as occurring prior to the piloting testing stage (Rodrigues, et al., 2017; Bradbury, et al., 2019).

### *Step 4*

In moving from *Step 3* to *Step 4*, intervention designers and developers transition from the iterative design and development (and subsequent pilot testing) of a concrete and material prototype, to planning for the digital health intervention's implementation. Of the four multi- and interdisciplinary partnership approaches, only two approaches, namely Approaches #13 and #14, discuss implementation, albeit briefly. Approaches #15 and #16, in comparison, do not mention or discuss an implementation stage in their processes. In Approach #14, Stage 3 defines a "Co-Implementation" phase that aims to "Identify Content and Implementation Options". In Stage 3, Approach #14 suggests the multi- and interdisciplinary team hold an "implementation workshop" where attention is diverted to developing a "Shared Implementation Strategy", and where activities involve creating shared support materials for training and handover, and developing a shared implementation action plan for real-world deployment. Similarly to Approach #14, Approach #13 specifies Component 3 for "Intervention Implementation", which recommends that the team create the same

implementation documentation, including a support training and handover materials and manuals, and a shared implementation action plan. Notably though, although both Approaches #13 and #14 mention implementation support materials and an implementation action plan, neither discuss implementation in detail, nor is sufficient practical guidance offered for supporting collaborative and cooperative efforts during the implementation process. Nevertheless, implementation is recognised in Approaches #13 and #14, yet is not acknowledged or specified as a process step in Approaches #15 and #16.

### *Step 5*

After planning for implementation and deployment in *Step 4*, the multi- and interdisciplinary team can transition to *Step 5* which focuses on conducting summative evaluation studies with the aim of assessing and determining the effectiveness of the digital health behaviour change intervention. Three of the four approaches, specifically Approaches #13, #14 and #15 discuss evaluation studies, whereas Approach #16, in contrast, does not discuss summative evaluation assessments. Noticeably, Approach #15 is the only approach that focuses specifically on evaluating the effectiveness of mHealth behaviour change apps, and is particularised to the physical activity context. In Approach #15, Step 6 aims to conduct "mHealth Intervention Prototype Evaluation" trial studies on the final app prototype (developed in Step 5) with real-world users in the target population group. Approach #15 specifies the trial period as spanning from a few months to a year (Morenga, et al., 2018). To evaluate the effectiveness of an mHealth behaviour change app, Approach #15 recommends using a mixture of quantitative and qualitative outcomes measures, including: behavioural (determinant) changes; health outcome changes; weight loss; app usability; app intervention adherence; app intervention adoption; app usage and frequency of use; app acceptance; and app feature preferences (Morenga, et al., 2018). Approach #13 mentions some of the same health related evaluation outcome measures, namely behavioural (determinant) changes, health outcome changes, and weight loss. However, resembling the argument earlier in *Step 3*, Approach #13 is dissimilar to Approach #15 in that it does not aim to evaluate any measures pertaining to the effectiveness of the digital platform as the mode of intervention delivery, but instead focuses specifically on measuring, assessing and determining the effectiveness of the intervention as a whole and its constituting component elements (BCTs). Although, similarly to Approach #15, Approach #13 explicitly discusses the value of mixed method evaluation measures, and articulates the benefit of triangulation (Morrison, et al., 2018). Approach #13 also reviews measuring and evaluating

the cost-effectiveness of a digital health behavioural change intervention, while Approach #14 makes reference to the APEASE Criteria which includes cost-effectiveness in its third criterion. The other two partnership approaches (Approaches #15 and #16) do not touch on cost-effectiveness. With regard to evaluation methods, Approach #15 discusses using cluster randomised trials (performed over a three-month period), whereas Approach #13 discusses using full-scale clinical experimental design methods, primarily randomised controlled trials (RCTs). In comparison to Approaches #13 and #15, Approach #14 only briefly touches on real-world trial evaluation studies in Stage 3 "Co-Implementation", although it does shed light on the debates concerning the "evidence conundrum", which describes the supremacy that has been assigned to traditional clinical randomised controlled trials as the most important and valid scientific method for evaluating health behaviour change interventions. Approach #14 elaborates by arguing that the "evidence conundrum" has become an unintended consequence of health intervention development approaches that have overemphasised the hard sciences over the soft sciences, favouring large-scale quantitative statistics over insightful qualitative evidence. Approach #14 therefore argues for the value in considering both a health sciences perspective and participatory design perspective to evaluation studies, thus accounting for both quantitative and qualitative evaluation evidence, and further stresses qualitative findings as demonstrating its contribution to "offer[ing] important complementary perspectives" (Carvalho, Jun and Mitchel, 2017, p.7). Overall, *Step 5* aims to assess, measuring and ascertain whether a digital health behavioural change intervention demonstrates real-world effectiveness with real end users in the target population group. The findings generated and analysed from the summative evaluation studies can then be used to further refine and improve the guiding principles (Approach #13) and the fully deployed digital health behavioural change intervention.

#### *Summary of Process Steps and Activities: Partnership Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.3.4, Figure Appendix I.5 provides a summarised high-level graphical illustration of the key themes and subthemes identified in the process steps (and activities) of the four multi- and interdisciplinary approaches in the Partnership Perspective category.

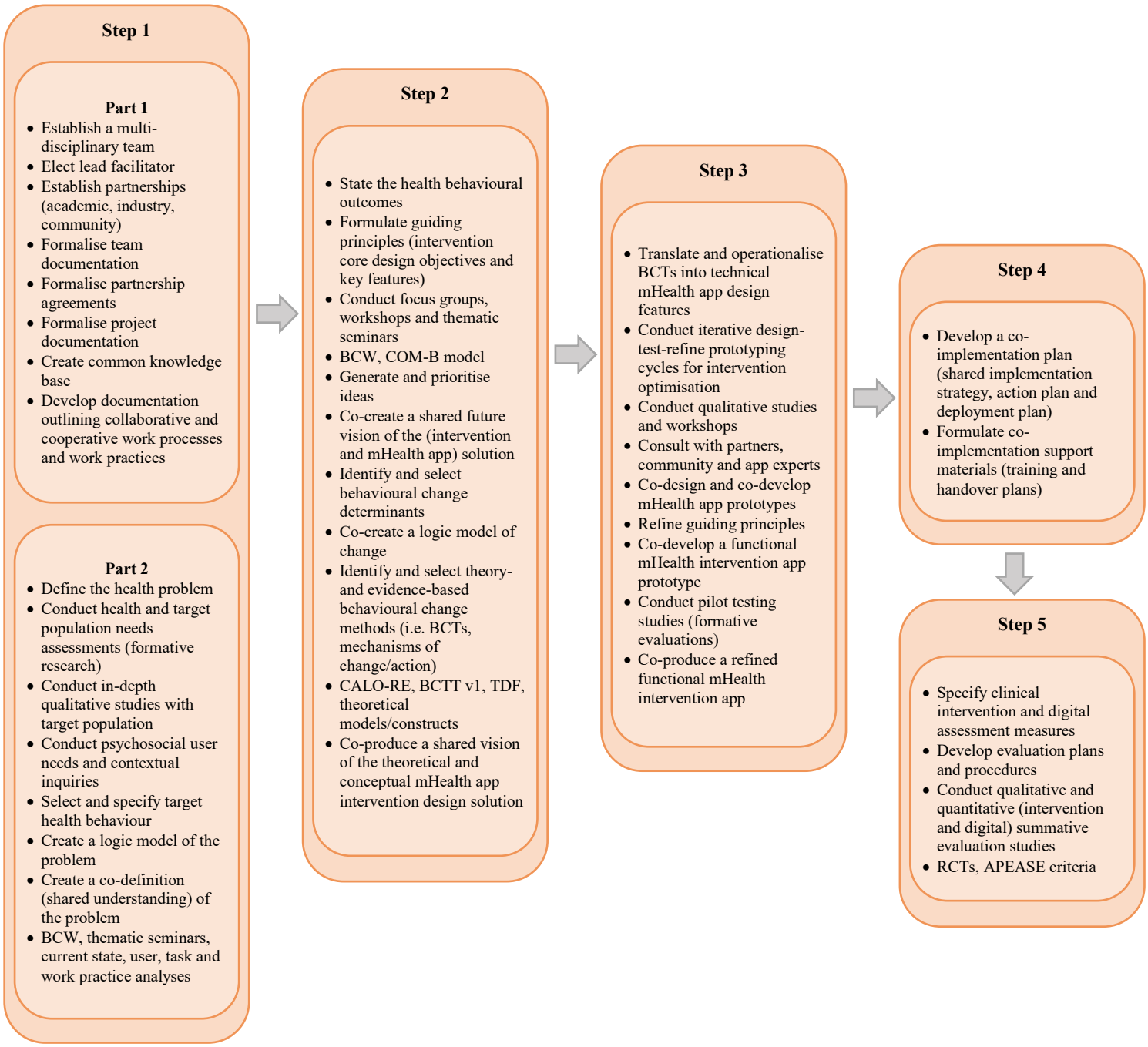



*Figure Appendix I.5: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Partnership Perspective Category [Researcher's own construction]*

### 6.4.3.5 Design Artefacts, Boundary Objects and Supporting Methods

*Step 1*

The first part of *Step 1* aims to establish and formalise a multi- and interdisciplinary team and partnership agreements prior to commencing the mHealth behaviour change intervention app development process. The main outputs from the multi- and interdisciplinary team's formation include: a list of all the team members, along with their disciplinary backgrounds (pinpointing

their worldview perspectives and implicit assumptive frameworks) and their proposed specialist knowledge, experience and skill contributions (tacit and explicit); a formal team contract (with all of the heterogeneous team member's buy-in, approval and sign-off); teamwork agreements (outlining the roles, influence and decision-making powers, responsibilities, work descriptions and work practices of each team member); documentation identifying and describing the roles, responsibilities and work descriptions and practices of the multi- and interdisciplinary team leader (appointed to manage, direct, support and guide the intervention development team) and the Health Informatics and Usability (HI-U) specialist (tasked as lead facilitator for the thematic seminars and research studies); partnership agreements (with academic researchers/institutions, community members/organisations, and third-party stakeholders); documentation and canvas outlining the team and partnership agreement values, principles and culture; recorded and disseminated minutes of the meetings (on the team's and the partnership agreements); guidelines and protocols regarding meetings, communications (incorporating trust, respect, empathy and empowerment), negotiation and decision-making processes, and conflict and tension resolution processes; team building guidelines; and team management protocols. The main outputs for the mHealth intervention project's start-up include: mHealth intervention project management documentation (specifying the project's goals/aims, objectives, vision, values and culture); a project model (or business model); a project funding model (related to the business and financial models); documentation outlining the details pertaining to the rules, regulations and guidelines for following the selected mHealth app intervention project development process; a report identifying and describing the initial project ideas. Furthermore, a common knowledge base is created as a shared point of reference for the team.

The second part of *Step 1* essentially involves the team creating a shared understanding of the health problem space and the target population group. In the Partnership Perspective category, this understanding can be discussed from three perspectives, namely the health sciences perspective, the information systems perspective, and the participatory design perspective. In terms of the health sciences perspective, the main input artefacts, objects and methods the team can use to gain a deeper understanding of the problem space and target market include: the Behaviour Change Wheel (BCW); the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model); focus groups; surveys and questionnaires; interviews; and thematic seminars. Also from the health sciences and health psychology perspective, Approach #13 emphasises the team utilise qualitative research methods and techniques (such as in-depth focus

groups and interviews) to gain an in-depth understanding of the target population groups' needs, characteristics, preferences and psychosocial contexts. With regard to the participatory design perspective, the main input artefacts, objects, methods and techniques the team can employ to better understand the health problem space and the target population group include: workshops; group discussions; reflective discussions; user interviews; focus groups; user forums; card sorting; user journeys; story-telling; metaphorical narrations; thematic network mapping; and 2D mapping. Concerning the information systems perspective, the main input artefacts, objects and methods the team can use include: task analyses; use case and object-oriented analysis (OOA) modelling techniques; user analyses; field observations; focus groups; interviews; surveys and questionnaires; and a master-apprenticeship and contextual design method (Approach #16); guidelines and worksheets for conducting thematic seminars (including homework sheets and questions, use case modelling and work scenario worksheets). For the three perspectives overall, the team can also make use of relevant literature and published findings from empirical studies, systematic reviews and meta-analyses, and similar materials can be used to carry out empirical studies (for example, photographs, audio recordings, visual recordings, worksheets, white boards, paper, pens and colouring materials). All in all, regardless of the perspective adopted, the input artefacts, objects and methods are referred to and employed by the multi- and interdisciplinary team, the key aims involve eliciting and gathering information that will provide a better understanding of users' characteristics, thoughts, attitudes, beliefs, needs, ideas, hopes and desires, interests, opinions, suggestions, preferences, barriers, facilitators and psychosocial contexts; all in relation to the health problem, the target health behaviour, the health outcome and the digital smartphone app platform via which the health behavioural change intervention is intended to be delivered to target users.

In terms of the health sciences perspective, the main outputs include: a statement of the health problem (in behavioural terms) and its context; a statement on the selected target health behaviour; a shared list of the behavioural challenges (based on the BCW); a Logic Model of the Problem (diagram); a target population group specification and description; a needs assessment and psychosocial context assessment of the target population group; a COM-B Behavioural Diagnosis table; and completed BCW worksheets. From the information systems perspective, the main outputs are linked to the outputs from the health sciences perspective, but also include: documentation on UML and OOA diagrams, narratives and case descriptions; user analysis report; task analysis report; context analysis report; reports on reviews and studies

regarding the technological and digital platform. From the participatory design perspective, the outputs will correspond to any (and all) of the artefacts, objects, methods and techniques employed by the multi- and interdisciplinary team. For example, a 2D map, a thematic network map, completed sorting and priority cards, user journey flow diagrams, et cetera. Overall, for all three perspectives, the team should produce documentation reporting on and summarising the findings from all of the literary and primary empirical qualitative and quantitative studies conducted. Ultimately, the team should produce a mutually intelligible "co-definition" output that provides a clear "shared understanding" (description and outline) of the health problem space (and scope) and the target population group.

### *Step 2*

The outputs from *Step 1* together with other artefacts, objects and methods are employed in *Step 2* to create a shared theoretical and conceptual solution for the mHealth behaviour change intervention app. Foremost, Approach #13 proposes the team develop "Guiding Principles", which are informed by the outputs from *Step 1.* In addition, other input artefacts, objects and methods the team can use to "co-create" a "shared vision" of the joint solution space from the health sciences perspective include: the Behaviour Change Wheel (specifically the BCW's intervention functions and policy categories); and the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model); a Logic Model of the Problem diagram (to inform the creation of a Logic Model of Change diagram); the 40-item CALO-RE Taxonomy (Michie, et al., 2011); the BCTT v1 93-item hierarchically clustered taxonomy (Michie, et al., 2013); and the Theoretical Domains Framework (TDF) (Michie, et al., 2005; Cane, O'Connor and Michie, 2012). Other input artefacts, objects and methods that can be used for both the participatory design and information systems perspectives include: brainstorming; insight cards; idea generation cards; scenarios; personas; creative and expressive techniques; and the "bus stop activity" (where participants provide feedback on the concepts behind existing similar commercial mHealth apps) (Approach #15). Input methods and techniques that the team can employ for all three perspectives in *Step 2* include: reviews of relevant literature and findings published from empirical studies, reviews of similar existing commercial mHealth apps, as well as findings analysed from the team's own primary qualitative and quantitative studies (with representatives of the target population group, or with various disciplinary experts). Examples of some qualitative and quantitative methods include: focus groups; interviews; questionnaires; surveys; workshops; thematic seminar discussions; and expert reviews.

Regardless of which perspective is adopted, the key intention in using these input artefacts, objects and methods is so that the team can develop a better understanding of the theoretical and conceptual solution space. This involves gaining an in-depth understanding of users' thoughts, attitudes, beliefs, needs, ideas, hopes and desires, interests, opinions, suggestions, preferences, barriers, facilitators and psychosocial contexts; all in relation to the aims and objectives of both the health behavioural change intervention (including its strategy components, theory-based methods and specific BCTs in relation to modifiable determinants) and the digital smartphone app platform.

The main outputs for *Step 2* include: documentation reporting on literature and empirical study reviews; documentation reporting on all primary qualitative and quantitative empirical studies performed by the team (including procedures and ethical approvals); a list of selected 'promising' modifiable determinants; a list of the selected theory-based methods (mechanisms of change); a list of possible 'most promising' BCTs (evidenced to influence the determinants); a list of the selected BCTs (along with rationale justifying each BCT's selection); a report of any theoretical models, constructs, taxonomies or methods used by the team (along with rationale); Determinants-BCT map (table) (Approach #15); a table identifying, describing, ranking and prioritising the theory- and evidence-based content modules (Approach #15); and a Logic Model of Change (diagram). Furthermore, and importantly, key outputs from the activities performed in *Step 2* are a "co-created", "co-developed" "shared vision" statement (document) of the theoretical and conceptual solution for the mHealth behaviour change intervention app, which can be referred to as a mutually intelligible common point of reference (boundary object) for all of the collaborating heterogeneous multi- and interdisciplinary team members. Moreover, another valuable output from *Step 2* emphasised by Approach #13 is the team's mutually agreed-upon "Guiding Principles", which comprises clear descriptions of (1) a specification of the intervention's core design objectives; and (2) a specification of the intervention's key features, which support the achievement of the core design objectives.

### *Step 3*

The main aim of *Step 3* is to translate the shared theoretical and conceptual design into a concrete and material design solution by performing a series of iterative design-test-refine prototyping cycles, leading to the development of an mHealth behavioural change intervention app prototype. The mHealth app prototype then subsequently undergoes pilot testing. Together with the outputs from *Step 2*, Approach #13 suggests using focus groups and observational

think-aloud sessions (with participant representatives of the target population group) as qualitative research methods to optimise the design of the mHealth app prototype. Notably, although Approach #13 uses qualitative research methods as inputs into the prototyping process, its focuses solely on a health sciences and health psychology perspective, and aims to optimise the persuasiveness, feasibility and acceptability of the intervention and its constituting components (BCTs). This is again at the expense of the information systems perspective of the digital platform. Therefore, in considering the information systems and participatory design perspectives, other prototyping input artefacts, objects and methods include: brainstorming; 2D prototyping; 3D prototyping; insight cards; idea generation cards; detailed scenario descriptions; personas; user workflows; information flows; UML modelling techniques; role-playing techniques; workshops and empirical studies on usability testing and user experience design testing (qualitative and quantitative measures); creative and expressive techniques (such as colourful moulding putty, shapes, fluffy pom-poms, beads, ribbons, picture and paper cut-outs, et cetera); thematic seminars and workshops (focusing on educating and showing participants the value of technological hardware, software, human-computer and interaction design considerations); and the "bus stop activity" (where participants provide feedback on the operationalised and instantiated design features of existing similar commercial mHealth apps) (Approach #15). Other input methods and techniques that the team can employ for all three perspectives in *Step 3* include: reviews of relevant literature, findings published from empirical studies, and feedback and recommendations from consultations with experts. Regardless of the perspective adopted, the main goal is to use various input artefacts, objects and methods as a means to iteratively design, test, refine and improve the concrete and material design of the mHealth app prototype, specifically in terms of how the intervention's components are technologically instantiated as app features and functionalities. Furthermore, following the prototype testing stage, the mHealth prototype can undergo pilot testing, during which the team can refer to and utilise various piloting studies techniques as input methods.

The main outputs for *Step 3* include: documentation reporting on reviews of app design features and functionalities from literature, empirical studies and existing similar commercial mHealth apps; documentation reporting on all primary qualitative and quantitative empirical studies performed by the team (including all analysed user feedback, participant and study design procedures, and ethical approvals); a BCT-App Feature Integration table (mapping intervention theories, strategies/BCTs and operationalised/instantiated app design features) (Approach #15); communication flows (maps and diagrams); detailed scenarios; technical specifications;

brainstorming session results; 2D prototypes; 3D prototypes; completed insight cards; completed idea generation cards; detailed personas; user workflows; information flows; interaction flows (between the user and app); role-playing scenario findings; representational analyses; and use case design-level modelling diagrams and narratives (Approach #16). Additional outputs intended for supporting the multi- and interdisciplinary teamwork during *Step 3* include: work practices and work scenarios (describing and illustrating different team members' contributions, activities and coordinated efforts); and mutually-developed syntactic and semantic language (terminology and description) artefacts that can support the transfer and translation of design-related knowledge (Approach #16). Another output is a further refined and updated version of the team's mutually agreed-upon "Guiding Principles" (Approach #13). Another important output for *Step 3* is a "co-design" document that outlines in detail how the theoretical and conceptual solution went through iterative design-test-refine cycles in its translation to become a concrete and material mHealth app prototype (reporting on and providing material evidence all of the prototype versions over time). Following the prototyping stage, if the mHealth app underwent pilot testing, additional document outputs are produced to report on the findings from the empirical pilot trial studies, and should stipulate any further refinements and improvements to the piloted mHealth app prototype. Ultimately, the key output by the end of *Step 3* is a concrete and material high-fidelity (prototype and pilot tested) mHealth app that is ready for subsequent implementation and summative evaluation studies.

### *Step 4*

The main inputs into *Step 4* are guidelines and templates for implementation strategies, implementation action plans and implementation support materials. The main outputs for *Step 4* include: a shared implementation strategy; a shared implementation action plan (statement with detailed work responsibilities and descriptions); shared support training materials; shared support handover materials. Only two of the four partnership approaches discuss implementation inputs and outputs, although neither discuss implementation artefacts and objects in detail.

### *Step 5*

Some of the main outputs from previous steps, together with new artefacts, objects and methods are used to inform *Step 5*, which focuses on conducting summative evaluation studies to assess and determine the effectiveness of the digital health behaviour change intervention. A fully

functional mHealth app and summative evaluation methods are the two key inputs for performing activities in *Step 5*. The most commonly referenced input method employed to evaluate the clinical effectiveness of a health behaviour change intervention are large-scale randomised controlled trials (RCTs), which stem from a health sciences perspective. Approach #13 adopts this perspective by focusing on assessing the clinical and objective outcome measures of the intervention, namely by measuring the cause-effect behavioural (determinant) changes, health outcome changes and weight loss. Besides traditional RCTs, other input evaluation artefacts and methods that can be used to assess not only the effectiveness of a health behaviour change intervention, but also the effectiveness of the digital platform include: cluster randomised trials (performed over a three-month period) (Approach #15); the APEASE Criteria (which also assesses cost-effectiveness from a business perspective); and other qualitative and quantitative usability and user experience methods (aimed at evaluating an app's adoption, acceptance, usability, sustainable usage, design features, and adherence). These alternate methods incorporate an information systems perspective, without forgoing the health sciences perspective.

The main outputs from *Step 5* include: documentation reporting on the details of the summative evaluation studies applied (including the study designs, participant particulars, study protocols and procedures, et cetera); reports on the results and analysis findings from the summative evaluation and trial studies; applications and documents with proof of ethical approvals; and a multi- and interdisciplinary team document reporting on and summarising all of the large-scale trial evaluation decisions made throughout *Step 5*. Furthermore, based on the results and triangulated findings from empirical summative studies, the team's mutually agreed-upon "Guiding Principles" can be further refined and updated (Approach #13). On a final note, the main output from *Step 5* is an mHealth app that has been further refined and improved upon based on the summative evaluation result findings.

### *Summary of Summary of Design Artefacts, Boundary Objects and Methods: Partnership Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.3.5, Figure Appendix I.6 provides a summarised graphical illustration of the key artefacts, design boundary objects and supporting methods identified as inputs and outputs into the process steps (and activities) of the four multi- and interdisciplinary approaches in the Partnership Perspective category.

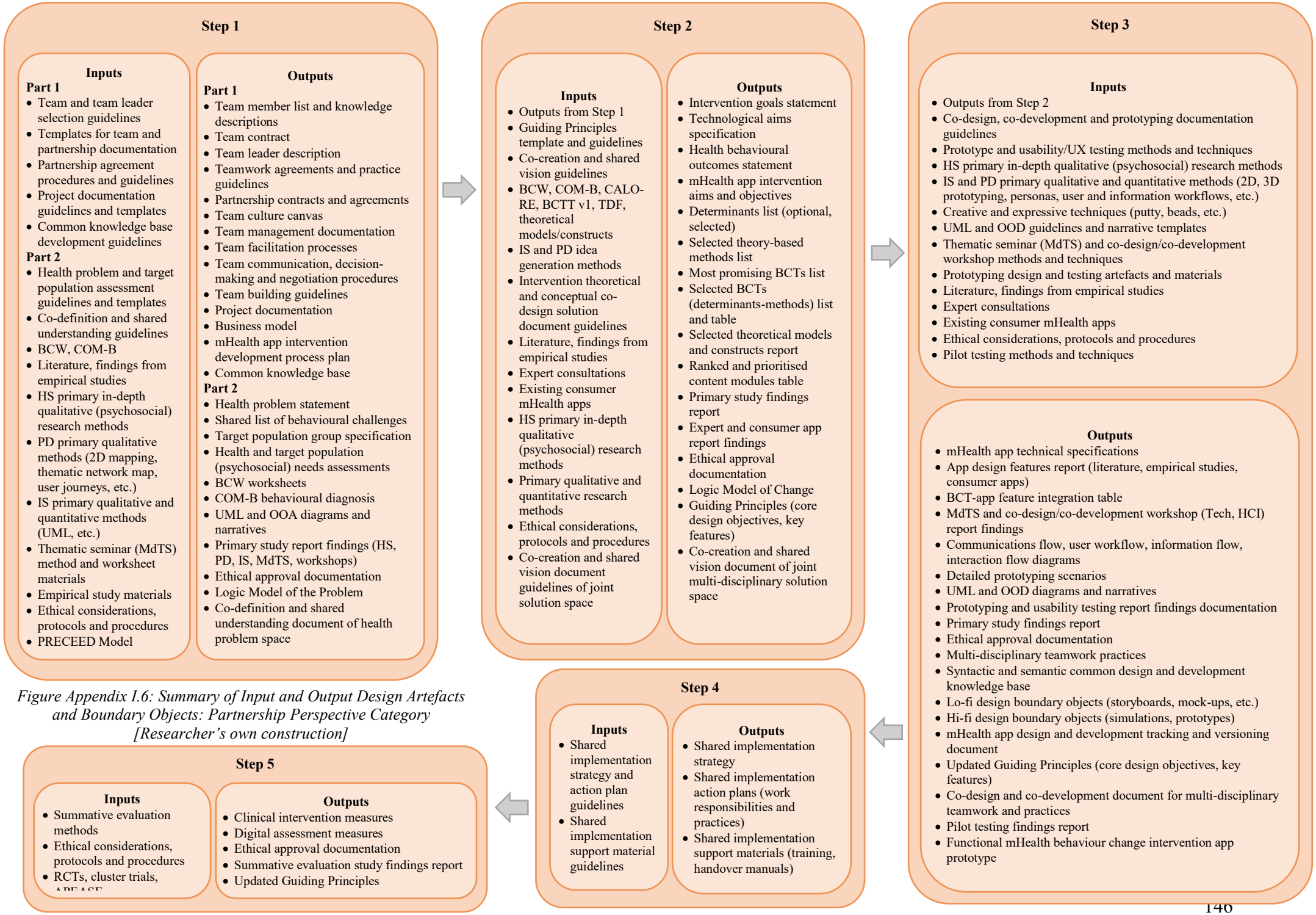



*Figure Appendix I.6: Summary of Input and Output Design Artefacts and Boundary Objects: Partnership Perspective Category [Researcher's own construction]*

#### 6.4.3.6 Knowledge Boundary Contributions

All four of the multi- and interdisciplinary approaches in the Partnership Perspective category latently and explicitly discuss knowledge transfer, translation and transformation across heterogeneous community of practice boundaries as a necessary and important requirement for improving the design of mHealth behaviour change intervention apps. A comparison across the four approaches reveals Approaches #13, #14 and #16 as contributing noticeably more to the knowledge boundary analysis findings than Approach #15. Nevertheless, all four partnership approaches discuss team communication, collaboration and cooperation as well as the creation and use of various common knowledge artefacts as (boundary) objects for facilitating, supporting and mediating collaborative design, development and evaluation activities and processes; although discussed to varying degrees. Approach #14, for instance, recognises how different philosophical and conceptual frameworks and perspectives inform different knowledge, expertise and skill contributions offered by diverse team members, and explicitly suggests "building on complementary strengths and different types of expertise" (Carvalho, Jun and Mitchell, 2017, p.8). In order to build on the complementary strengths, common languages, common meanings and common interests need to be established and adhered to by all participating heterogeneous team members throughout the mHealth app intervention development process. An initial acknowledgement of the different perspectives held by various members may be valuable to begin with, which is something Approach #15 offers in its proposed suggestion to "jointly formulate [a] short, concise and actionable 'points-of-view' statement", which could function as a boundary object for providing a clear articulation of team members' diverse viewpoints.

At the syntactic knowledge level, attention is given to the use of common lexicons and syntaxes as boundary objects for enabling the efficient and effective representation (or classification), storage, transfer and retrieval of language (terminology and descriptions). References to syntactic objects are made by Approach #13 which briefly mentions the CALO-RE Taxonomy (Michie, et al., 2011), Approach #15 which discusses and actively employs the BCTT v1 Taxonomy (Michie, et al., 2013), and Approaches #14 and #15 which both utilise the TDF (Michie, et al., 2005; Cane, O'Connor and Michie, 2012). In comparison to Approaches #13 and #15, Approaches #14 and #16 do not mention theory- and evidence-based language ontologies or taxonomies.

In transitioning from the syntactic knowledge boundary to the semantic knowledge boundary, all four partnership approaches discuss issues and proposed solutions concerning the different interpretations of meaning between heterogeneous team members. Approach #13 articulates a valuable discussion in its unambiguous and explicit acknowledgement of the different interpretations of meaning for the same terminology between the fields of health sciences and health psychology (from one overarching perspective), and the fields of information systems and user-centred design (from another overarching perspective). Words such as 'usability', 'acceptance' (or 'acceptability'), 'adherence', 'user experience', 'engagement', 'persuasiveness' (or 'persuadability'), 'satisfaction', 'enjoyment' (or 'enjoyable'), 'motivation' (or 'motivating'), and 'convincing' are examples of key terminology that offer different semantic interpretations of meaning between the two health science and information systems perspectives. Approach #13 distinguishes between these alternate interpretive meanings by clarifying the differences in the health sciences and health psychology focus on the health behavioural change intervention and its constituting components (BCTs), and the information systems and user-centred design focus on the instantiation of digital and smartphone app design features as interactive interface and end user elements. Critical thought processing through a boundary object theoretical lens reveals that artefacts operating at a semantic knowledge layer should cater for such differences in interpretation of meaning at a localised (individual-site) level, yet should simultaneously offer team members a shared understanding of common meanings at an abstract and general (multi-site) level (Star, 2010). This feature represents interpretive flexibility, a core characteristic of knowledge boundary objects that enables communication, collaboration and cooperation amongst multi- and interdisciplinary team members (Approach #16).

Also on a semantic knowledge level, Approaches #14 and #16 strongly emphasise the importance of establishing a "common knowledge base" (Carvalho, Jun and Mitchell, 2017, p.13) as a "common ground" (Scandurra, Hägglund and Koch, 2008a, p.557) foundation from which the multi- and interdisciplinary team can create shared understandings of the joint problem and solution spaces. Approach #14, for instance, explicitly centres its process around the use of methods (such as workshops) and tools (such as the BCW, thematic network maps and the APEASE criteria) from health behavioural sciences and participatory design to create common artefacts including: co-definitions and shared understandings (of the mutual problem space); co-designs, co-developments and shared visions (of the joint solution space); co-implementations and co-evaluations (of the application and testing spaces). Similarly,

Approach #16 discusses multi- and interdisciplinary team collaboration as centring on an established "mutual understanding" (Scandurra, Hägglund and Koch, 2008a, p.557). These 'common', 'shared' and 'mutual' artefact understandings quintessentially provide multi- and interdisciplinary team members with a concrete means of translating knowledge across boundaries in order to "learn about" the differences, dependencies and similarities in their various interpretations of meaning and informatic and work practice/process needs and arrangements (Carlile, 2002, p.452; Star, 2010). Furthermore, Approach #14 discusses the value in co-creating a mutually shared health behavioural intervention design and development strategy (or plan) that "focus[es] on a solution that embraces [all of] the complementary roles performed" by each member of the multi- and interdisciplinary team (Carvalho, Jun and Mitchell, 2017, p.13). However, in order to embrace all of the team members' different knowledge, expertise and skill contributions, Approach #14 suggests that the team actively engage in prioritisation exercises, during which the different and similar work activities, actions and solutions are collectively envisioned, arranged and coordinated between participating members. The multi- and interdisciplinary team therefore constructs a shared intervention design and development strategy (or plan) of mutually agreed-upon priorities that caters for differences and dependencies in a complementary and coordinated effort (Approach #14). Approach #16 is similar in its discussions on the use of multi- and interdisciplinary thematic seminars (MdTSs) as a participatory and collaborative method for creating a common platform that incorporates the various information needs, work routines/practices and work processes of each contributing team member at all stages of the intervention development plan. Approach #16 also notes how this common platform (or plan) should clearly outline the points of intersection between heterogeneous team members, and should specify how work practices and processes are to be coordinated within an "entire cooperative framework" (Scandurra, Hägglund and Koch, 2008a, p.560). Considerations for various social, organisational, commercial/business, cultural and environmental factors related to and influencing the team's cooperative and coordinated work practices and processes should also be taken into account (Approach #16). Further supporting and framing this collaborative and cooperative development plan is "a common picture of what the [health information] system should be", or in particular research case, "a common picture of what the [mHealth behaviour change intervention app] …should be" (Scandurra, Hägglund and Koch, 2008a, p.562). Importantly, Approach #16 notes that team members should aim to employ (or create) shared methods that offer an in-depth understanding of "true cooperative" design and development work within their specific contexts of use and practice, and cautions against the use of "conventional

methods" (which are not multi- and interdisciplinary in nature) as they are likely to lead to a fragmented picture and understanding of the various team members' interpretations of meaning and informatic and work practice/process needs and arrangements (Scandurra, Hägglund and Koch, 2008a, p.559). Moreover, Approach #16 latently discusses the value of mutually agreed-upon guidelines and documents as boundary objects for facilitating, supporting and mediating the translation of knowledge between community of practice members from heterogeneous disciplines and specialisations.

In progressing from a semantic level to a pragmatic level, all four partnership approaches recognise and discuss prototypes as integral to the health intervention development process, yet neither of them identify prototypes as valuable pragmatic boundary objects for facilitating, supporting and mediating knowledge transformation. Approaches #14, #15 and #16 discuss the utility and usefulness of prototypes as collaborative and cooperative work objects, and mention a range of low- to high-fidelity versions from paper prototypes (such as sketches) to digital prototypes (such as 2D and 3D simulations). Approach #16 touches on the value prototypes offer as mediating objects that continuously allow for the incorporation of newly emerging and evolving requirements over time. Furthermore, prototypes provide teams with a concrete and tangible means of communicating and negotiating about design and development decisions, and also allow for periods of reflection and perspective-taking, which together feeds the generation of new insights and understandings over time, therefore "triggering innovative thinking" and the joint creation of new solutions and new transformative knowledge (Scandurra, Hägglund and Koch, 2008a, p.565). Approach #14 similarly explains how a multi- and interdisciplinary team actively engaging in the collaborative and collective iterative process of prototype creation and refinement informs the ongoing generation of better future design solution visions.

On a related note, in order for multi- and interdisciplinary teams to collaboratively and collectively transform knowledge on a pragmatic level, Approach #16 emphasises the significance in creating common aims, goals, objectives and strategies to minimise the risk of misunderstandings and misinterpretations of meaning, and establish "a good working environment" that fosters productive collaborative and cooperative heterogeneous efforts and knowledge contributions. Approach #14 touches on a similar discussion, describing a pragmatic aspiration for active multi- and interdisciplinary team member involvement, engagement and effort as driven by three core defining values. These include namely: "having

a say" (which refers to the ability each team member has in impacting the decision-making processes with regard to their perspectives of the design and development issues, and their visions for future solutions); "mutual learning" (which fosters a "deep experience of exchange" between team members as they recognise that every participant has something valuable to contribute and learn from the collaborative effort); and "co-realisation" (which refers to the dynamics of making changes together, building on complementary strengths and perspectives, and harnessing different types of knowledge, expertise and skill contributions) (Carvalho, Jun and Mitchell, 2017, p.7-8). Moreover, according to Approach #15, emphasis should be given to allowing for "shared and equal decision-making" throughout the collaborative co-design and co-development process. However, at a pragmatic level, creative innovation and knowledge transformation essentially entails active negotiation efforts and decision-making processes that generally result in the sacrificing of power and interests (Carlile, 2004). Consistent equal decision-making power becomes an ideal that is not realistically achievable in practice, particularly considering how increases in novelty lead to increases in complexity and the amount of effort required to manage new unknown and unfamiliar differences and dependencies. In addition, increases in novelty lead to increases in novel uncertain circumstances which requires team members to negotiate around conflicts of interest and to abandon and trade-off their previously invested knowledge, therefore putting their knowledge "at stake", which often negatively deters team members' willingness to change the knowledge and interests of their own discipline (Carlile, 2004, p.557). However, if team members are willing to negotiate at the pragmatic boundary and are prepared to make knowledge- and interest-driven trade-offs and sacrifices, then new knowledge transformations and innovative and fruitful technological design solutions are likely to evolve and emerge (Approach #16). Furthermore, Approach #16 discusses the significant value knowledge brokers, who are "fluent in the languages" of all participating disciplines, can offer to the multi- and interdisciplinary team's active communication, collaboration, cooperation and negotiation processes throughout the digital health intervention's design, development and evaluation project (Scandurra, Hägglund and Koch, 2008a, p.559).

#### 6.4.3.7 Limitations and Lessons Learned

Limitations, gaps, weaknesses and lessons learned can be identified across all four of the multi- and interdisciplinary approaches in the Partnership Perspective category. The following short discussion does not provide an extensive critical analysis on all possible limitations or lessons learned, but instead touches on a few noteworthy points given the adopted theoretical lens

(boundary object perspective) utilised to frame the conducted cognitive thought trials and judgement-making processes. With this being said, an initial cross-comparison reveals Approaches #14 and #16 as limited in their orientations toward health interventions for primary healthcare service delivery and medical contexts (such as Approach #14's case application to urinary tract infections in hospital emergency departments). This limitation is a weakness in that it is not cognisant or particularised to health promotion and self-management health behaviour change intervention contexts. An additional limitation of Approach #14 is that it is generalised to guide the development of health behaviour change interventions across all modes and platforms of delivery. Approach #16 shares a similar limitation in that it is focused on healthcare information systems for hospitals and medical practices; technological systems that have notably different characteristics, capabilities and limitations in comparison to digital mobile devices and smartphone app platforms. Approaches #14 and #16 are therefore both limited in their contributions regarding application contexts and digital/technological platforms of intervention delivery. Associated with this limitation is the provision of guidance for translating, operationalising and instantiating BCTs into digital interactive design features. Approaches #13, #14 and #16 are all limited in that their processes fail to account for these necessary and important translation, operationalisation and instantiation design activities. In sharp contrast, Approach #15 is the only approach of the four partnership approaches that offers insights into these activities in that its process accounts for digital mHealth app design feature operationalisations and instantiations.

Despite these shortcomings, Approaches #14 and #16 still nevertheless offer other forms of noteworthy insights and lessons learned. Approach #14, for instance, offers valuable insights in the creation and use of shared and common artefacts (knowledge boundary objects) at all stages of the health behaviour change intervention design and development process. Approach #16, for example, proposes the adoption and utilisation of computer supported cooperative work (CSCW) and collaborative thematic seminar methods, both of which are strongly orientated around the continuous creation and use of boundary objects and design artefacts. Furthermore, Approach #16 proposes the recruitment and selection of a HI-U specialist to manage the multi- and interdisciplinary team and facilitate the series of thematic seminars. HI-U specialists represent a form of knowledge broker who, according to Approach #16, are "fluent in the languages of both healthcare professionals and system engineers [designers and developers]", and who are not located within one particular discipline, but operate at the boundaries between intersecting and collaborating disciplines, therefore constituting

significantly valuable mediators and brokers throughout the whole health intervention development process. In contrast to Approaches #14 and #16, Approaches #13 and #15 are particularised to the digital and smartphone app health behaviour change intervention contexts, respectively, and have both been employed to design and develop mHealth physical activity apps *HelpMeDot!* (Matthews, et al., 2017) and *OL@-OR@* (Verbiest, et al., 2018), correspondingly. These case applications provide valuable context-relevant insights and lessons learned regarding their focus on self-management mHealth physical activity apps intended for targeting the dual intra-(primary)interpersonal socioecological level of health promotion. Approaches #14 and #16, on the contrary, are limited in their broader socioecological focus on the broader organisational, community and societal levels, rather than the individual and interpersonal levels.

On an alternate note, another noteworthy limitation is that Approaches #13, #15 and #16 are comparably more time and resource intensive than Approach #14. Approaches #13, #15 and #16 employ in-depth qualitative interviews, participatory co-design focus group workshops, and collaborative and cooperative thematic seminars, respectively; all of which demand a considerable amount of time and resources to initiate, maintain and conduct repeatedly throughout the health intervention design and development process. However, with regard to Approach #13, its adoption and use of in-depth qualitative interviews yields valuable lessons learned in that its focus is framed from a health psychology perspective rather than a digital or systems perspective. This different perspective provides insights gained in recognising the interpretive flexibility of commonly used terminology (such as ‘usability’, ‘acceptance’, ‘adherence’, ‘user experience’, ‘engagement’, ‘persuasiveness’, ‘satisfaction’ and ‘enjoyment’) that are orientated towards the intervention strategies and components (BCTs) and the intervention as a whole, rather than the digital mHealth app design features and the interactive smartphone app platform. Notably though, while this health perspective offers lessons learned, it also exhibits limitations of Approach #13. Most markedly, a weakness of Approach #13 is that it is not a standalone approach, nor is it sufficient to replace current existing multi- and interdisciplinary approaches. The authors of the paper on Approach #13 overtly recognise this important limitation, proclaiming that the Person-Based Approach should be utilised in conjunction with and complementary to other theory-based and evidence-based approaches, and that in order to derive its full potential, it should be usefully incorporated within another multi- and interdisciplinary holistic approach that integrates human-centred design and information systems frameworks. Moreover, in keeping with the mention of

resource demands, all four partnership approaches are limited in that they require (and implicitly assume) all of the multi- and interdisciplinary team members to possess a sufficient, yet significant, amount of specialist knowledge, skill and expertise in order to interpret, make-sense-of, understand and apply the respective steps/stages and activities of their proposed processes. This implies a need for considerable past experience and substantial tacit knowledge and understanding, which in turn discourages and hampers the adoption, use and application of the four approaches by inexperienced, untrained and amateur health (promotion) behaviour change app intervention designers and developers.

Regarding the nature of the partnership approaches, Approach #14 is limited in that its process does not advocate for or prescribe an iterative, rapid or cyclical approach to intervention design and development. This is a noteworthy limitation given the agile and rapidly evolving nature of the mobile device and smartphone app industries and environments. Related to the nature of the approaches are the perspectives they offer. Insights are gained from Approaches #14 and #16 which incorporate aspects of an organisational perspective. Although this analysis does not seek to extract factors pertaining to the organisational level, it does consider themes and subthemes applicable to the business perspective, which considers elements concerning the commercial, product development and consumer markets. Business and product development perspectives are valuable in their applicability to the commercial smartphone app industry and consumer app market stores. Also related to the approaches' natures and perspectives are their proposed and prescribed steps, stages, components and activities. In terms of notable limitations, Approach #16 does not at all discuss summative evaluation activities or methods, which is a considerable weakness in comparison to Approaches #13, #14 and #15. Approach #13, however, is limited in its favoured focus on large-scale clinical experimentation methods (such as RCTs) and again its adoption of in-depth qualitative studies, both of which require a significant amount of time and resources to conduct. In comparison, Approach #14 provides insights gained with a discussion on the "evidence conundrum" and makes reference to the APEASE criteria, while Approach #15 advocates for a mixture of qualitative and quantitative evaluation methods aside from traditional RCTs.

Lastly, a critical cross-comparative analysis of the four multi- and interdisciplinary partnership approaches reveals none of them as recognising or discussing any concepts or constructs regarding community of practice theory, boundary object theory and knowledge boundary theory. This limitation has already been acknowledged and discussed in Subsections 6.4.1.7

and 6.4.2.7, and as already noted, the failure of the four approaches to identify themes and subthemes relevant to the boundary object view further verifies the novelty of the proposed theoretical framework (lens). Yet, at the same time, yields less rich comparative and thematic analysis findings from the four partnership multi- and interdisciplinary approaches. On a final note, a range of other noteworthy limitations, gaps, weaknesses and lessons learned can be referred to in Table C under Appendix H; although, to reiterate, these points are neither copious nor comprehensively extensive.

### 6.4.4 A Critical Analysis of Multi- and Interdisciplinary Approaches: An Integrative Perspective

Multi- and interdisciplinary approaches that offer a predominant integrative perspective are pertinent to analyse because they contribute multi- and interdisciplinary viewpoints that consolidate and amalgamate knowledge from different disciplines/specialisations and different worldview perspectives. Integrative approaches are valuable in that they seek ways of bridging the divides between heterogeneous communities of practice, all of which contribute necessary and relevant knowledge, expertise, skills and practices to the collaborative design, development and evaluation of mHealth behaviour change intervention apps. The Integrative Perspective category covers approaches to digital and mHealth behaviour change intervention app design, development and evaluation that are described as: holistic (Approach #17); multidisciplinary (Approaches #18 and #19), interdisciplinary (Approach #20); and integrative (Approaches #17, #19 and #20). Overall, the four approaches provide insight into the integrative main themes and subthemes that are relevant and valuable to the multi- and interdisciplinary mHealth physical activity behaviour change intervention app design, development and evaluation process.

The template criteria (Table 6.5) is used to critically analyse each of the four approaches. Table D in Appendix H provides a full detailed summary analysis of the integrative approaches in terms of the nine template criteria. The seven main themes outlined in Section 6.4's introduction provide sub-headings for analysing, comparing, examining and critiquing the four approaches, presented in a written report discussion. Box 6.7 identifies the four multi- and interdisciplinary approaches classified in the Integrative Perspective.

- **Approach #17** Holistic Framework for Developing Digital Health Behaviour Change Interventions: TUDER
- **Approach #18** A Multidisciplinary Approach for the Agile Development of Gamified mHealth Behaviour Change Intervention Apps
- **Approach #19** A Multidisciplinary Approach for Developing Health Behaviour Change Intervention Persuasive Technology
- **Approach #20** Behavioural Science-Informed User Experience Design (BSUED) Process for mHealth Behaviour Change Intervention Apps

*Box 6.7: Multi- and Interdisciplinary Approaches: Integrative Perspective*

*[Source: Researcher's own construction]*

#### 6.4.4.1 Aims and Contexts of Integrative Perspective Approaches

The four multi- and interdisciplinary approaches categorised in the Integrative Perspective share a common aim, which Crutzen (2014, p.1) succinctly describes as the intention *to combine and join "the best of both [or more] worlds"*. In other words, the integrative approaches share a common aim: *to bridge the divides between independently established, albeit intersecting, heterogeneous practice communities, and consolidate and fuse knowledge from different disciplines/specialisations and different worldview perspectives, in order to produce better designed and more effective mHealth behaviour change intervention apps.* Furthermore, at each stage of the collaborative process, integrative approaches aim to support and facilitate multi- and interdisciplinary communication, collaboration and cooperative work practices within teams, often emphasising the importance of a common syntax and shared ontology. Approach #17, for instance, aims to provide holistic and comprehensive digital health behaviour change intervention guidance to designers and developers by integrating models from health psychology, persuasive systems design and mHealth app design, into one "unified" digital health intervention taxonomy (Wang, 2019, p.37; Wang, et al., 2019, p.4). Approaches #18 and #19 propose multidisciplinary approaches that aim to integrate gamification, and persuasive technology and situated cognitive engineering, respectively. Approach #20 provides a mHealth app intervention development process that aims to integrate behavioural science theory (stemming from health sciences) and user experience design (stemming from information systems design).

Two of the four integrative approaches (Approaches #17 and #19) aim to guide the development of health promotion behavioural change interventions intended for delivery via digital technologies in general, including various health technologies and mHealth apps

specifically. In comparison, the two other approaches (Approaches #18 and #20) aim to provide multidisciplinary guidance for designing and developing mHealth behaviour change intervention apps in particular. Three of the four approaches, namely Approaches #17, #19 and #20, have been used to develop mHealth intervention apps targeting physical activity behaviour change specifically. Approach #20, for example, was used to design, develop and evaluate three different mHealth physical activity apps from three distinguishable perspectives: *Analytic (Cognitive)*; *Social*; and *Affective (Emotional)*. Approach #18, in contrast, has been used to develop a smoking cessation app, *CigBreak*; although, the approach offers insights and lessons learned that are valuable and applicable to the mHealth physical activity behaviour change intervention app context.

With regard to target audience, all four approaches have been used for designing, developing and evaluating digital health interventions intended for the individual and interpersonal socioecological levels of health promotion. Overall, all four approaches emphasise multi- and interdisciplinary collaborative team involvement from the start of a project, and identify methods, artefacts and objects to support collaborative knowledge sharing and work efforts during the design, development and evaluation process. Three of the four approaches (Approaches #17, #18 and #19) review and/or draw from four or more existing approaches, including *Intervention Mapping* (Approach #1), *The CeHRes Roadmap* (Approach #2), *The BIT Model* (Approach #7), *The IDEAS Framework* (Approach #8), *The mHealth App Intervention Development Process* (Approach #9), and *The Person-Based Approach* (Approach #13). However, one approach, Approach #20, does not harness or draw from any existing approaches.

For purposes of length, the Integrative Perspective category's critical thematic and comparative analysis findings for sub-headings 6.4.4.2 to 6.4.4.7 are extracted to Appendix I. One summary table and two summary figures for the Integrative Perspective process and artefact/boundary object themes and subthemes are also included in Appendix I.

#### 6.4.4.2 Actors and Community of Practice Members

All four multi- and interdisciplinary approaches in the Integrative Perspective category identified a heterogeneity of actors and community of practice members in the collaborative digital health and mHealth behaviour change intervention development team. Only one of the approaches, Approach #19, mentions "stakeholders" as actors involved in the development

process. Approach #19 describes stakeholders in terms of the broader socioecological and healthcare systems, including interpersonal, community, financial (funding) and organisational actors. Additionally, it discusses stakeholders in terms of the business ecosystem, mentioning suppliers, lead product producers, competitors, and persuasive technology and behaviour change support system suppliers. Approach #18, despite not mentioning "stakeholders" per se, does discuss the participatory and collaborative involvement of specialist advisors from formal organisations and programmes, such as smoking cessation advisors and certified exercise trainers. Approach #18 was the only approach, out of the four, to identify "practitioners" in terms of health practitioners and public health intervention practitioners. None of the four approaches reviewed discuss collaborative involvements with "third-party" stakeholders such as industry partners, policy makers, legislative and regulatory officials, government agencies and local authorities. Approach #18 does, however, mention that intervention developers should be aware of, and adhere to, regulatory frameworks and emerging standards concerning mHealth interventions. Two of the approaches, Approaches #19 and #20, make brief mention of "consumers" as end users of mHealth behaviour change apps, which falls within the Consumer Health Informatics field of study. Two of the approaches, with the exceptions of Approaches #19 and #20, identify the participatory involvement of research groups or communities and researchers in the multi- and interdisciplinary team. Approach #17 specifically refers to "DHI [digital health intervention] researchers" as the actors involved in the design, development and evaluating of digital health behavioural change interventions such as mHealth smartphone apps for physical activity (Wang, et al., 2017; 2019). None of the four integrative orientated approaches discussed "partnerships", "contracts" or "agreements" explicitly, which is a notable limitation given these approaches essentially aim to integrate and bridge divides between different disciplines and heterogeneous specialist expertise. Related to the discussion on partnerships, none of the four multi- and interdisciplinary approaches mention collaborations with the commercial app industry, particularly mobile and/or smartphone app companies. This finding is concerning since working with consultants from consumer app market companies can be beneficial to the mHealth design and development process as well as the final app product output (which ultimately gets released to the public via consumer app market stores, such as the Google Play and Apple stores).

On another note, in comparison to the multi- and interdisciplinary approaches reviewed in the other three perspective categories, the terms "intervention designers" and "intervention developers" are used noticeably less by authors of articles in the Integrative Perspective

category. Approach #17 is the only approach of the four that employs these two terms (that is, "intervention designers" and "intervention developers"), and identifies "DHI [digital health intervention] developers" specifically. Approach #19 does use the term "intervention developers", but fails to recognise "intervention designers". Both Approaches #18 and #20 adopt different viewpoints and interpretations of the terms "designers" and "developers", with Approach #18 referring to "game designers", "game developers" and "app developers" – which assumes a technological perspective – and Approach #20 mentioning "product designers" – which assumes a consumer product development perspective. Discrepancies and subtle nuances in terminological use and the interpretive flexibility surrounding such terminology becomes apparent within the emerging multi- and inter-disciplinary digital health and mHealth behaviour change intervention app arenas. Furthermore, Approach #19 is the only approach to make reference to the collaborative involvement of system (software) engineers and cognitive engineers in the multi- and interdisciplinary intervention development team. None of the four approaches reviewed in this analysis discuss the role or appointment of a multi- and interdisciplinary team "facilitator", "lead(er)" or "manager" who can be tasked with responsibilities in organising, managing and coordinating the collaborating team members. Approach #18 does, however, mention the appointment of a "trained facilitator" and an "assistant" facilitator to guide and facilitate focus group sessions during steps two and seven of the seven-step mHealth app development process. Approach #18 also mentions the appointment of a facilitator who is responsible for chairing all multi- and interdisciplinary team meetings throughout the process, and who is tasked with documenting and logging all decisions made by the collaborating team.

Three of the four approaches (Approaches #18, #19 and #20) discuss experts and professionals, who possess specialist expertise and skills, as being active actors and members in the multi- and interdisciplinary team. Approach #17 does not explicitly refer to experts or particular expertise, but does latently discuss actors who hold distinctive disciplinary knowledge and skills. Of the four integrative multi- and interdisciplinary approaches, Approach #18 is the only approach that places significant emphasis on the formative establishment of an "expert multi- and interdisciplinary [design and development] team" from the get-go, describing experts as professionals with appropriate and sufficient expertise and experience in designing, developing and evaluating mHealth behaviour change intervention apps. Approach #19 refers to the involvement of experts from different disciplines (such as human-computer interaction and user interface designers, health psychologists, cognitive and system engineers, to name a few),

while Approach #20 refers to experts who hold expertise and skills specifically in programming and user testing. Approach #19 discusses how different disciplinary backgrounds informs different interpretations and use of terminology (or jargon), which can lead to misunderstandings between multi- and interdisciplinary team members. The authors of Approach #19 (Blanson Henkemans, et al., 2015, p.54) therefore emphasise the necessity and value in establishing consensus terminology that can offer heterogeneous team members a *lingua franca* as a means to "improv[ing] communication and collaboration between the different experts involved". With regard to mentioning specific actors with particular disciplinary expert knowledge and skills, Approach #18 identifies multi- and interdisciplinary team members to include: senior smartphone app developers; computer scientists; academic researchers; senior health psychologists; senior medical sociologists; game designers; game developers; health behavioural experts; and specialist advisors. Approach #19 identifies multi- and interdisciplinary team members to include: health psychologists; human factors engineers; cognitive engineers; system engineers; information systems designers and developers; persuasive technology designers; human-computer interaction specialists; and health behavioural experts. Approach #20 identifies team members to include: health behavioural scientists; human-computer interaction specialists; product designers; exercise physiologists; physicians; and user experience designers. In comparison to the other three approaches, Approach #17 identifies all multi- and interdisciplinary team members as falling under the "DHI developers" umbrella term, and does not distinguish between community of practice actors.

On an alternative note, with regard to target population (end user) representatives, all four integrative approaches discuss the direct and indirect engagements and involvements at specific stages of the design, development and evaluation process. Participants, as target user representatives, are generally referred to in terms of partaking in, and providing feedback on, piloted prototypes and final intervention products. In addition to this type of user participation involvement, Approach #20 also discusses conducting qualitative ethnographic interviews with target population representatives during the third (mHealth app prototype design and development) step of the five-step process. Approaches #18 and #19 also mention conducting qualitative studies with participant user representatives to better understand the needs and preferences of the intended target population. Moreover, Approach #19 advises further participatory target (end) user engagement at all stages of the health behaviour change intervention development process, specifically mentioning the value sensitive design (VSD)

method as a possible continuous target user involvement option. Notably, Approach #19 advises this, but does not adopt or incorporate the VSD method in its process. Similarly to the discussions in the Health Sciences and Information Systems/Technology Perspective categories (Subsections 6.4.1.2 and 6.4.2.2, respectively), references made to target (end user) representative involvements in these four integrative multi- and interdisciplinary approaches are not intrinsically partnership or participatory design perspectives, and hence are not classified under the third Partnership Perspective category.

#### 6.4.4.3 Perspectives, Underlying Theories, Models, Tools and Existing Approaches

All four of the multi- and interdisciplinary approaches reviewed in the Integrative Perspective category adopt approaches and perspectives of health promotion, health psychology and health behavioural sciences to digital health and mHealth behaviour change intervention development. The socioecological approach is also adopted in all four approaches, in which they all recognise the influence of environmental influences, yet all concentrate specifically on the dual intra-inter(primary)personal socioecological levels of health promotion intervention. Approach #17, for instance, focuses on individualistic and social theoretical constructs often employed in health psychology intervention research, and incorporates them into the proposed Holistic Approach (The TUDER Framework). Approaches #18, #19 and #20, in like manner, direct their focus towards identifying and incorporating health psychology theory at the individual level (mentioning factors such as mood, goal-setting, self-efficacy, reinforcement and enjoyment) and the primary social (interpersonal) level (mentioning factors such as social support, family and friends, social networking). This dual-level intervention focus is compatible with the technological functionalities offered by and through digital mobile devices and smartphone app platforms. Furthermore, all four approaches analysed in the Integrative Perspective category incorporate participatory approaches, and all four do so by employing participatory methods to conduct user testing studies, such as prototype piloting testing and iterative test-refine improvement cycles. These participatory methods correspond with user-centred design approaches; which all four integrative approaches also incorporate at various stages of their established processes. Approach #20 is the only approach that explicitly mentions user-centred design, although Approaches #17, #18 and #19 frequently discuss conducting usability studies, prototype testing, heuristic evaluations, cognitive walkthroughs and focus groups with target population (end user) representatives (samples), which quintessentially, albeit latently, illustrates a user-centred design perspective. Human-centred

design is latently acknowledged in Approach #17, particularly in relation to understanding human behaviour in its first step of a four-step process; and is adapted from the human-centred design perspective adopted in The CeHRes Roadmap (Approach #2). Human-centred design is also integrated into Approach #19, particularly given the approach's grounding in Situated Cognitive Engineering (sCE). In contrast, human-centred design is not incorporated in Approaches #18 and #20. On a separate, yet related, note, user experience design is considered in two of the four approaches. Approach #19 considers user experience design when evaluating interactions with digital persuasive health promotion behaviour change interventions, while Approach #20 positions user experience design as fundamental to its proposed integrated process. Human-computer interaction is acknowledged in all four approaches, although explicitly incorporated in Approaches #17 and #19, but latently in Approaches #18 and #20, through discussions on usability and users' interactions with digital software features. User interface design and considerations for how design features are presented on digital screens are built into Approaches #19 and #20. In comparison, Approaches #17 and #18 do not mention user interface design heuristics or considerations. None of the four approaches incorporate a design thinking perspective. Approaches #17, #19 and #20 recognise a systems thinking perspective and approach.

Related to the systems thinking perspective, human factors engineering and systems cognitive engineering, specifically sCE, informs the base upon which Approach #19 is developed. The other three approaches differ from Approach #19 in that they do not adopt systems engineering approaches or perspectives. Often associated with the information systems and software engineering disciplines is the agile development process. The Agile Systems (or Software) Development Lifecycle process is integrated in Approach #18, but is not recognised or mentioned the other three approaches. One approach of the four reviewed (Approach #19) incorporates object-oriented analysis and design (OOA and OOD, or OOAD) and Unified Modelling Language (UML) techniques in a few of its process components; which are technical approaches popularly utilised within the information systems discipline. More specifically in terms of technological focus, all four of the multi- and interdisciplinary approaches reviewed in the Integrative Perspective category embed an mHealth intervention and digital technology intervention perspective. Only two of the four approaches, however, make explicit reference to the commercial app industry and consumer app markets. Approach #18 overtly discusses releasing consumer health (promotion) behaviour change intervention (smartphone) apps on the Google Play and Apple stores. Approach #20 refers to the Consumer Health Informatics

field by mentioning “consumer-driven healthcare” and explicitly identifies two smartphone software operating systems (OSs), namely Android and iOS; which directly correspond with the two app stores mentioned by Approach #18, respectively. In addition to the integration of mHealth and smartphone app and the consumer smartphone app market perspectives, persuasive technology and persuasive systems design perspectives are fundamentally integrated in Approaches #17 and #19. Approaches #18 and #20 do not acknowledge persuasive technology or persuasive systems design. Approaches #18 and #20 are also different to Approaches #17 and #19 in that they recognise and integrate aspects of product design and development approaches. Approach #18, notably also integrates gamification as an elemental component of their approach to change health behaviour, unlike the other three approaches which do not recognise the influence of gamification. As a final note on perspectives and approaches, with regards to health behavioural intervention context, all four multi- and interdisciplinary approaches are intended for targeting healthy lifestyle (behaviour) modification and wellbeing management; two of which (Approaches #17 and #20) largely focus on physical activity behaviour change, and two of which (Approach #18 and #19) mention physical activity behavioural change interventions in relation to the health promotion context.

Theoretical bases underpin three of the four multi- and interdisciplinary approaches reviewed in the Integrative Perspective category, namely Approaches #17, #18 and #19. Approach #17 thoroughly reviews and incorporates aspects of existing theoretical frameworks, models and approaches from a diversity of fields relevant to the design, development and evaluation of mHealth and digital health behaviour change interventions. The authors explain that “due to their inter-disciplinary nature, DHIs [digital health interventions] are guided and influenced by theories … from different research communities” and propose a “holistic framework [TUDER] that embeds [various] theories”, essentially arguing for digital and mHealth health behavioural change interventions that are multi- and interdisciplinary, yet theory-based (Wang, et al., 2019, p.1). Approach #19 is similar to Approach #17 in that it describes its approach as “generat[ing] building blocks from theory originating from different relevant disciplines” and that the approach “is expected to contribute to a sound [theory-based] design rationale” (Blanson Henkemans, et al., 2015, p.49). In comparison, Approach #18 references particular psychological therapy models, and also incorporates logic model theory and program theory into certain steps of the seven-step mHealth intervention development process; specifically the WK Kellogg Foundation’s (2006) Logic Model of Development Guide. In contrast to

Approaches #17, #18 and #19, Approach #20 is not informed by any particular theoretical frameworks, models or approaches, but does iterate several times the importance of designing and developing mHealth promotion behavioural change interventions that are theoretically-derived and/or theory-based, arguing for "theoretical rationale" to underpin mHealth smartphone apps (Hekler, et al., 2011, p.1). Furthermore, with regard to individual and interpersonal theories, only two of the four integrative approaches (Approaches #17 and #20) explicitly discuss and include evidence-based health psychology theories and models that are frequently referred to in digital health behaviour change intervention research, and mHealth apps for physical activity behaviour change in particular. Some of the theories mentioned in these two approaches are: social cognitive theory (SCT); self-determination theory (SDT); self-regulation theory (SRT); self-efficacy theory (SET); social learning theory (SLT); theory of reasoned action (TRA); theory of planned behaviour (TPB); goal setting theory (GST); theories of social support (SS); social facilitation theory (SFT); the transtheoretical model (TTM); the health belief model (HBM); theories of automatic behaviour and habit formation; the integrated behaviour model (IBM); and the Health Action Process Approach (HAPA). For the exact identification of which individual and interpersonal theories are identified in Approaches #17 and #20, refer to Table D in Appendix H. While Approaches #17 and #20 explicitly reference individual and interpersonal theories, theoretical models and theoretical constructs, Approaches #18 and #19 latently incorporate many of the mentioned theories in the demonstrated applications of their approaches. On another note, only one of the four approaches (Approach #17) identifies and actively integrates theory on just-in-time adaptive interventions (JITAIs); which has shown to be valuable for the development of effective mHealth behaviour change intervention apps, particularly physical activity and sedentary behaviour (Muller, Blandford and Yardley, 2017; Nahum-Shani, et al., 2018; Direito, et al., 2019).

The significant value in employing theory-informed and evidence-based (health) models and tools is recognised in all four multi- and interdisciplinary approaches in the Integrative Perspective category. All four approaches identify and make use of one coding taxonomy, namely the CALO-RE Taxonomy, while three (with the exception of Approach #20) identify and use the BCTT v1. The reason for Approach #20 not discussing or employing the BCTT v1 coding taxonomy is that it was published two years subsequently (Michie, et al., 2013) to the BSUED Process's (Approach #20's) original publication (Hekler, et al., 2011). None of the four approaches acknowledge or discuss a taxonomy of development, namely the Taxonomy

of Behaviour Change Methods (TBCM). In addition, none of the four integrative approaches reference, mention or recognise any of the following: the Theoretical Domains Framework (TDF); the CONSORT-EHEALTH Checklist; the PRECEDE-PROCEED Model; the Health-ITUEM; the RE-AIM Framework; the Ritterband Model; or the APEASE Criteria. The Behaviour Change Wheel (BCW) and the COM-B Model (Capability, Opportunity, Motivation and Behaviour Model) is only briefly cited in the article on Approach #19, although neither the BCW nor the COM-B Model are utilised in the approach. Approaches #17, #18 and #20 do not recognise the BCW or the COM-B Model. Furthermore, none of the four approaches mention or discuss either the Functional Triad or Fogg's Behavioural Model (FBM). However, in comparison, Approach #17 does recognise and actively integrate the Persuasive Systems Design Model (PSDM). The other three approaches do not incorporate the PSDM, although the publication on Approach #19 cites it, but does not utilise it in any of the three components of the approach. On another note, in comparison to the other approaches selected and reviewed in the other three perspective categories, multi- and interdisciplinary approaches in the Integrative Perspective category employ and utilise theory-informed and evidence-based (health) models and tools that have not yet been identified or discussed. Approach #18, for instance, makes use of existing gamification taxonomies and gamification models, and also uses the British Standards Institution Code of Practice for Health and Wellbeing Apps. Approach #19 integrates State-Of-The-Art (SOTA) research as well as the Technology Readiness Level (TRL) measurement tool. Notably important for this research project's study context, Approach #20 also utilises formally published Physical Activity Guidelines for informing the design and development of mHealth behaviour change intervention smartphone apps.

Three of the four integrative approaches, namely Approaches #17, #18 and #19 review and/or leverage and draw from existing multi- and interdisciplinary approaches. Approach #17 reviews and integrates aspects of Approaches #1, #2, #7 and #8, along with Wendel's Approach (Wendel, 2013), for informing the TUDER Framework and its four-step digital health behaviour change intervention development process. While Approach #17 leverages four existing multi- and interdisciplinary approaches, Approach #18 reviews and discusses six, but only to compare them against the approach itself, and not draw from them. Approach #18 is compared to Approaches #3, #6, #8, #9, #13 as well as the User-Centred Design Model for Designing Consumer mHealth Apps (Schnall, et al., 2016). The latter model (Schnall, et al., 2016), although reviewed in the article on Approach #18, was excluded from this particular

theoretical analysis for failing to meet the selection criteria (outlined in Table 6.4). As for Approach #19, four approaches are actively leveraged and fundamentally integrated into the three-component approach, namely the Intervention Mapping protocol (Approach #1), the Situated Cognitive Engineering (sCE) Method (Neerincx, 2011), the Behavioural Intervention Technology (BIT) Model (Approach #7), and the Combined BIT Model and Intervention Mapping "Best of Both Worlds" Approach (Crutzen, 2014, p.1). In sharp contrast to Approaches #17, #18 and #19, Approach #20 does not review, leverage or draw from any existing multi- and interdisciplinary approaches.

#### 6.4.4.4 Nature of Approaches and Process Steps and Activities

*Nature of the Approaches*

All four of the multi- and interdisciplinary approaches in the Integrative Perspective category share iterative, cyclical, cumulative, theory-based and evidence-based characteristics. In terms of a cumulative nature, Approach #19, for instance, describes the gathering, collecting and establishing of "building blocks" (from both a health behavioural intervention perspective and a persuasive technology perspective) in component one of a three-component process. With regards to theory, the authors of Approach #17 describe their approach as a process for developing "theory-based digital health interventions for behaviour change" (Wang, et al., 2019, p.1), and the authors of Approach #18 describe their approach as a process for creating "theoretically grounded" mHealth behaviour change intervention apps (Edwards, et al., 2018, p.1). In relation to the iterative and cyclical characteristics of all four integrative approaches, the authors of Approach #17 define their process as adopting an iterative nature, and graphically illustrate their process with several cycles (feedback loops) between all four steps. Similarly, the graphical illustration of Approach #19 depicts two cycles (feedback loops) between components 3.1 and 2.2 and components 3.2 and 2.1. Furthermore, Approaches #18 and #20 describe their process as allowing for the rapid cyclical design, development and evaluation of mHealth behaviour change intervention apps. In terms of linearity, Approaches #17, #18 and #20 are linear in nature. Approach #19, in comparison, incorporates both linear and non-linear qualities, in that components one, two and three are linear in nature, whereas components 2.1 and 2.2 and components 3.1 and 3.2 are non-linear in nature. On another note, only two of the approaches (Approaches #18 and #19) are described by their authors as "collaborative". Only one approach, specifically Approach #17 is explicitly referred to by its authors as "comprehensive" in nature. On a final point, Approach #19 is the only approach

where the authors explicitly describe their process as offering "practical" guidance to multi- and interdisciplinary team members for the development of digital health behaviour change interventions.

### *Process Steps and Activities*

All four of the multi- and interdisciplinary approaches in the Integrative Perspective category provide a series of steps (stages, phases or components) that constitute prescribed processes for guiding intervention designers and developers in developing digital- or technology-based health behavioural change interventions by integrating, consolidating or unifying heterogeneous disciplinary knowledge. The various process steps (stages, phases or components) for each integrative approach is provided Table Appendix I.4. For each of the four processes, Table D in Appendix H provides detailed descriptions, sub-steps and activities for each step, as well as the methods, tools and artefacts used and/or produced at each step.

*Table Appendix I.4: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Integrative Perspective Category [Researcher's own construction]*

| **Approach #17** | **Approach #18** | **Approach #19** | **Approach #20** |
|---|---|---|---|
| Step 1:<br>Targeting | Step 1:<br>Forming an Expert Multi- and interdisciplinary Design Team | Component 1:<br>Generation | Step 1:<br>Create Behavioural Science Summary Sheets |
| Step 2:<br>Understanding | Step 2:<br>Defining the Problem and Establishing User Preferences | Component 2:<br>Specification | Step 2:<br>Develop Motivational Frames |
| Step 3:<br>Designing | Step 3:<br>Incorporating the Evidence Base | Component 2.1:<br>Specification of Intervention (Macro Level Persuasion) | Step 3:<br>Target Population Assessment and Prototype User Experience Piloting |
| Step 4:<br>Evaluating and Refining | Step 4:<br>Integrating Gamification | Component 2.2:<br>Specification of Interaction (Micro Level Persuasion) | Step 4:<br>Develop Functional Prototypes |
| **Toolboxes and Workflow** | Step 5:<br>Adding Behaviour Change Techniques (BCTs) | Component 3:<br>Evaluation | Step 5:<br>Evaluate and Refine Functional Prototypes |
| Toolbox 1:<br>Behavioural Theories | Step 6:<br>Developing a Logic Model and Investigating Causal Pathways | Component 3.1:<br>Evaluation of Interaction | |
| Toolbox 2:<br>DHI Taxonomy | Step 7:<br>User Testing and Developing the Final App Product | Component 3.2:<br>Evaluation of Intervention | |
| Workflow | | | |

### *Step 1*

A comparative review of the four multi- and interdisciplinary approaches in the Integrative Perspective category reveals only one approach, namely Approach #18, as explicitly discussing

steps and activities pertaining to the formation and formalisation of a multi- and interdisciplinary team at the initial onset of a digital health intervention development process. Approach #18 defines Step 1 as "Forming an Expert Multi- and interdisciplinary Design Team", during which a team of experts from a diversity of fields is established with the intention of offering various expertise and experience to aid in the design and construction of an mHealth behaviour change app. The types of heterogeneous experts suggested to actively participate in and contribute towards this process were identified and discussed earlier in Subsection 6.4.4.2 "Actors and Community of Practice Members". To lead the team, Approach #18 emphasises the selection and involvement of a multi- and interdisciplinary team facilitator who is tasked with the responsibility of coordinating, managing and directing the team through the mHealth app development process. Approach #18 recommends that the multi- and interdisciplinary design team meet face-to-face once a week throughout the mHealth intervention development process, that meetings are chaired by the team facilitator, and that all of the team's procedures, protocols and decisions are formally documented and logged at each stage of the seven-step process. Furthermore, since focus groups form an essential part of Approach #18's process, a recommendation is made to select a trained and experienced focus group facilitator, as well as an assistant (from the multi- and interdisciplinary team) who can help and assist the facilitator. In contrast to Approach #18, Approaches #17, #19 and #20 do not explicitly stipulate or mention the establishment of a multi- and interdisciplinary team before commencing the digital intervention development process, although their formation is implicitly assumed and implied prior to process onset.

Once a multi- and interdisciplinary team has been established and formalised, the team members can commence the mHealth behaviour change app development process by continuing with other activities comprised in *Step 1*. Approaches #17, #18 and #19 share the aim to define the health problem, the target health behaviour, the health behaviour outcome(s), and the target population group. Approach #17 specifies these activities in Step 1 "Targeting (the User Group, Health Problem and Behaviour)", while Approach #18 incorporates them under Step 2 "Defining the Problem and Establishing User Preferences", whereas Approach #19 includes them in Component 1, the "Generation (of Building Blocks)". When defining the problem space, Approach #17 recommends that intervention designers clearly articulate the linkages and relationships between the selected health problem, target health behaviour, target population and health behavioural outcome. For example, an mHealth behaviour change intervention app to promote an increase in walking (the target health behaviour) to increase

physical activity (the health behavioural outcome) of young adults (the target population group) in order to prevent the development of noncommunicable diseases such as cardiovascular disease and type II diabetes. Approach #17 explains that these defined linkages ought to be guided by a preliminary high-level intervention goal, such as aiming to design an mHealth intervention app intended for changing young adults' physical activity behaviour, and that this goal be informed by literature and evidence-based empirical studies. Furthermore, to gain a deeper understanding of the problem space, Approaches #18 and #19 suggest that the multi- and interdisciplinary team explore evidence-based determinants and causal factors that have shown to positively influence the target health behaviour and health behavioural outcome. Approach #19 refers to this as a (health and at-risk target population) needs assessment, which also requires an investigation into understanding the characteristics of the at-risk target population group, their general current state of wellbeing, quality of life and prevalent health conditions, and what key determinants are evidenced to successfully influence the target health behaviour for that specific target population group. This assessment can be based on existing literature, published findings from empirical studies, or by conducting primary qualitative (formative) research with representatives of the target population group, using methods such as focus groups, interviews, workshops, questionnaires and surveys. Once the selected health, behaviour, group and outcome has been defined, Approach #17 suggests completing items one to three on the TUDER Checklist's first category "Targeting", which helps provide the team with a clear and concise shared point of reference as to what specifically is being targeted.

While a clearly defined problem space and health needs assessment helps the team establish the building blocks from the health behavioural intervention perspective, Approach #19 suggests that the team also establish building blocks from the technology perspective. Together these building blocks constitute the knowledge base for Component 1 "Generation". From a technological perspective, the team aims to clearly define the operational demands (also referred to as the operational needs), which explicates the work and activity conditions for target users interacting with the digital health behaviour change intervention technology. According to Approach #19, operational demands (or needs) also covers the characteristics, roles, tasks and contexts pertinent to the target users' work, processes and activities. In addition, the team can consider what human factors design theory, principles, data and methods are applicable to the technological health intervention project's context, and specify the ways in which users' wellbeing and the overall system's (or digital device's) performance can be optimised. Moreover, Approach #19 strongly recommends that the team conduct a

technological state-of-the-art (SOTA) assessment, which considers the current highest level of development for a particular digital device (such as smartphone technology), and aims to generate insight into the hardware and software that is potentially applicable and beneficial to facilitate the health behaviour change intervention's delivery (such as in relation to smartphone apps). This assessment also offers insight into the technology readiness level (TRL) of a particular digital device, which helps the team gauge the device's (im)maturity, and provides an indication as to what financial investment will be required to fully design and develop the digital health intervention. Collectively, the operational demands (or needs), human factors, SOTA and TRL assists the team in generating building blocks from a technological perspective, which when paired with the building blocks from a health behavioural perspective, offers an enriched understanding of the digital health behaviour change app intervention space. In addition to and complementing Approach #19's recommended technological perspective, Approach #18 suggests that the team aim to "Establish User Preferences" in Step 2, during which target users' preferences for mHealth intervention app design features and strategy components (BCTs) are explored in relation to the target behaviour and desired health outcome. Approach #18 advises that focus groups be used to elicit users' preferences, and that more than one session may be held if necessary. Furthermore, Approach #18 discusses that the team create a table outlining the key themes and subthemes identified as important for designing the mHealth app's features. An example of this table particularised to the mHealth (promotion) behaviour change app intervention context on an intra-interpersonal level is provided in Approach #18 (Edwards, et al., 2018, p.6).

### *Step 2*

In transitioning from *Step 1* to *Step 2*, a critical comparative review of the four integrative multi- and interdisciplinary approaches indicates a move from understanding and defining the problem to conceptualising a theoretical and design solution for the digital health behaviour change intervention. *Step 2* is divided into three main activities. Firstly, *Activity 2.1* aims to outline the performance and change objectives for the mHealth intervention. Secondly, *Activity 2.2* is orientated towards developing a theoretical base for the mHealth app's conceptual design by reviewing, identifying and selecting appropriate theory- and evidence-based intervention strategies (BCTs), evidence-based standards, guidelines and codes of practice, and gamification strategies (techniques). Lastly, *Activity 2.3* aims to translate and operationalise these strategies, standards and techniques into practical mHealth app design features and

technical app characteristics, incorporate persuasive systems design principles, as well as develop a workflow that specifies the conditions and context for the intervention's delivery. The activities pertaining to *Step 2* are extracted from and informed by a range of steps, stages, components and tools from all four multi- and interdisciplinary approaches in the Integrative Perspective category. Activities and tools are drawn from two steps in Approach #17, specifically Step 2 "Understanding (the Human Behaviour and Change Process)" and Step 3 "Designing (the Intervention Strategies, Characteristics and Workflow)". From Approach #18, activities are elicited from four steps, including Step 3 "Incorporating the Evidence Base", Step 4 "Integrating Gamification", Step 5 "Incorporating Behaviour Change Techniques (BCTs)", and Step 6 "Developing a Logic Model and Investigating Causal Pathways". With regard to Approach #19, a variety of tasks are extracted from Component 2 "Specification" in particular, which comprises Component 2.1 "Specification of Intervention (Macro Level Persuasion)" and Component 2.2 "Specification of Interaction (Micro Level Persuasion)". The last of the four integrative approaches, Approach #20 includes Step 1 "Create Behavioural Science Summary Sheets" and Step 2 "Develop Motivational Frames"; both of which provides insight into activities relevant to the conceptual design of mHealth behaviour change intervention apps.

### *Step 2: Activity 2.1*

Based on the preliminary intervention goal conceived in *Step 1*, *Activity 2.1* in *Step 2* aims to clearly outline and detail the specifications to guide the design and development of the health behaviour change intervention and digital device (technological platform) as intended by the multi- and interdisciplinary team. Approach #19 suggests that the specification be defined for the intervention (on a macro level of persuasion) and for the interaction (on a micro level of persuasion); hence considering both the health sciences perspective and technological perspective, respectively. For both the intervention and interaction, the team defines the performance objectives in relation to the theory- and evidence-based determinants (from *Step 1*), out of which the change objectives are determined. According to Approach #19, change objectives are defined as the most immediate target of an intervention or interaction that are understood to best address the defined target health behaviour and digital device interaction challenges, respectively. To illustrate the objectives, Approach #19 recommends drawing two Change Objective Matrices (tables), one for the intervention level and the other for the interaction level. Examples of the Change Objective Matrix for the Intervention (table) and the

Change Objective Matrix for the Interaction (table) are provided in Approach #19 (Blanson Henkemans, et al., 2015, p.53).

### *Step 2: Activity 2.2*

Once *Activity 2.1* is complete, *Activity 2.2* involves developing a theoretical base for the intervention of the mHealth behaviour change app. Creating the intervention's theoretical base can be approached by either one of two ways, or possibly even both ways, at the discretion of the multi- and interdisciplinary team. The first possible way to perform *Activity 2.2* is to initially establish a theoretical base for the intervention by following Approach #17's guidance to identify and use either one health (psychological, cognitive and behavioural) theoretical model (such as SCT, TTM, or HAPA), or to draw from a set of complementary theories or theoretical constructs (such as attitude, self-efficacy, motivation, identity, goals, action planning, or perceived barriers). Approach #17 emphasises that these theories be applicable to the selected target population, the health problem, the target health behaviour, and the health behavioural outcome (defined in *Step 1*), and that the linkages and mappings be evidence-based and explicitly clarified by the team. Toolbox 1 (Behavioural Theories), proposed with Approach #17, provides intervention designers and developers with key evidence-based individual and (primary)interpersonal health (psychology) behavioural theories for developing the digital intervention's theoretical base. Furthermore, the preliminary work published by the authors prior to the release of Approach #17 discusses theoretical models and constructs particularised to the smartphone mHealth app and physical activity contexts specifically (Wang, et al., 2017, p.4-13). The second possible way to carry out *Activity 2.2* is to not develop an initial theoretical base from theoretical models or constructs, but instead to begin by identifying and selecting theory- and evidence-based intervention strategies (BCTs) by reviewing literature and findings published from empirical studies. A comparison of the four integrative approaches reveals the second option is discussed in Approach #17's Step 3 "Designing (the Intervention Strategies)", Approach #18's Step 3 "Incorporating the Evidence Base", Step 4 "Integrating Gamification" and Step 5 "Incorporating Behaviour Change Techniques (BCTs)", Approach #19's Component 2.1 "Specification of Intervention (Macro Level Persuasion)", and Approach #20's Step 1 "Create Behavioural Science Summary Sheets". A third possible way employs both the first and second options simultaneously, by developing a theoretical base from theoretical models and constructs, and by reviewing, identifying and selecting theory- and evidence-based BCTs concurrently.

To select theory- and evidence-based BCTs as intervention strategies (components) for the mHealth behaviour change app, Approach #17 provides a novel contribution to the multi- and interdisciplinary knowledge base with its integrated Digital Health Intervention (DHI) Taxonomy (Toolbox 2). The DHI Taxonomy offers an adapted integration of two reliable and validated models, specifically the BCT Taxonomy v1 (Michie, et al., 2013) and the PSDM (Oinas-Kukkonen and Harjumaa, 2009). Together, these two models consolidate techniques and principles from two perspectives; namely, the health behavioural sciences and health psychology perspective, and the persuasive technology and persuasive systems design perspective; representing the health sciences and technological perspectives, respectively. The DHI Taxonomy (Toolbox 2) can be referred to in the journal article publication on Approach #17 (Wang, et al., 2019, p.6) and two of its supplementary materials (Wang, et al., 2019, p.8, Multimedia Appendices 2 and 3). In comparison to Approach #17, Approaches #18 and #19 discuss utilising the 40-item CALO-RE Taxonomy and the 93-item hierarchically clustered BCTT v1 taxonomy to identify and select BCTs that have shown to be efficacious in changing the target behaviour for the defined target population group. In complementing the approach offered by the first option, Approach #19 suggests drawing from other theoretical models and constructs (such as the ASM Model, the Zone of Proximal Development, and Social Penetration Theory) alongside the CALO-RE and BCTT v1 taxonomies. Similarly, Approaches #18 and #20 recommend identifying and selecting evidence-based theoretical models and constructs by reviewing literature, meta-analyses and findings from empirical studies, and by performing primary qualitative studies with target population representatives (using methods such as focus groups and surveys). Moreover, Approaches #17, #18 and #20 emphasises the involvement of a heterogeneous team of experts, all of which can contribute alternate perspectives to further enrich the BCT identification and selection process. These specialists predominately originate from health science related fields, including health psychologists, health behavioural change interventionists, academic researchers, behaviour-specific experts (such as qualified exercise and sports professionals for the physical activity context), and healthy lifestyle and wellbeing management specialists. Once the most promising and salient BCTs have been selected, Approaches #18 and #19 suggest creating a BCT list. Approach #20 adds to the richness of the BCT list by recommending that the team create "Behavioural Science Summary Sheets" (also referred to as "Cheat Sheets"), in which each listed BCT is accompanied by a clear description (definition), explanation of what the technique does, and an example of how the technique can be applied in the intervention. Approach #19 discusses a similar creation, suggesting that a matrix (table) be drawn outlining

how each selected BCT will be translated into practical strategy applications in the intervention, and mapping the BCTs and strategy applications back to the defined change objectives (created in Activity 2.1). Two "Behavioural Science Summary Sheet" examples can be referred to in the paper on Approach #20 and in its supplementary material (Hekler, et al., 2011, p.2). An example of Approach #19's matrix can be referred to in its journal article publication (Blanson Henkemans, et al., 2015, p.53). To further enrich these sheets and matrices, Approach #20 recommends using lay terms, rather than specialist jargon, when describing, explaining and translating the BCTs, in order to simplify and enable cross-disciplinary communications and knowledge transfer between collaborating team members. Another way to succinctly summarise the details for Activity 2.2 is by completing items four to six under the second "Understanding" category on Approach #17's TUDER Checklist, which helps provide the team with a clear and concise shared point of reference as to what theoretical models, constructs and BCTs have been selected. Furthermore, Approach #18's Step 6 suggests developing a logic model of the mHealth app's theoretical and conceptual design, which describes the program theory underpinning the intervention's design, and illustrates the intended causal pathway linkages between all of the intervention's assumptions, theories, strategies (BCTs), inputs, activities (practical strategy applications), outputs, outcomes, and impacts.

Along with the theory- and evidence-based BCTs, Step 3 "Incorporating the Evidence Base" in Approach #18 proposes referring to and utilising existing evidence-based standards, guidelines and codes of practice to help guide the team identify and elicit critical aspects applicable to the optimisation of the health behavioural change intervention. Examples include the MRC Guidelines (Approach #3), the British Standards Institution Code of Practice for Health and Wellness Apps, the latest up-to-date evidence-based guidelines for smoking cessation, and the WHO recommendations for physical activity engagement. Moreover, unlike Approaches #17, #19 and #20, Approach #18 offers a valuable contribution with Step 4 "Integrating Gamification". The integration of gamification strategies and techniques into mHealth intervention apps has shown to be significantly efficacious and effective in persuading positive changes to individuals' health behaviours, and to physical activity in particular (Althoff, White and Horvitz, 2016; Edwards, et al., 2016; LeBlanc and Chaput, 2017; van Dyck, 2017; Kappen, Mirza-Babaei and Nacke, 2018; Cotton and Patel, 2019). Approach #18's step involves identifying and selecting gamification strategies and techniques by reviewing theory- and evidence-based gamification models and taxonomies, and relevant target behaviour

literature, meta-analyses, empirical studies and existing mHealth apps. Experts in game design and development can collaborate with the multi- and interdisciplinary team in contributing specialist knowledge and experience applicable to the intervention project. The team should also ensure that the selected gamification strategies and techniques complement and align with the theoretical base underpinning the intervention. Examples of gamification strategies and techniques include: goal setting; competition; challenges; customisable avatars; rewards and leaderboard charts; unlocking levels, content and special items; social comparison; and social connectivity and networking. Approach #18 suggests creating a table listing the selected gamification strategies and techniques, along with their descriptions and practical application examples.

### *Step 2: Activity 2.3*

Having reviewed, identified and selected suitable theory- and evidence-based BCTs, evidence-based standards and gamification strategies, and having created supporting tables and matrices, the team can continue with *Activity 2.3*. *Activity 2.3* involves conceptually translating and operationalising the BCTs, standards and gamification strategies (from Activity 2.2) into design features for the mHealth behaviour change app. To clarify, Activity 2.2 focuses primarily on the conceptual design of the health behaviour change intervention and its components (including BCTs, standards and gamification strategies). Whereas Activity 2.3 focuses primarily on the conceptual design of the smartphone app (as a digital platform) though which the intervention and its components are delivered to the user. In comparing the four integrative approaches again, technological and user interaction tasks are discussed in Approach #17's Step 3 "Designing (the Intervention Strategies, Characteristics and Workflow)", Approach #18's Step 4 "Integrating Gamification" and Step 5 "Incorporating Behaviour Change Techniques (BCTs)", Approach #19's Component 2.2 "Specification of Interaction (Micro Level Persuasion)", and Approach #20's Step 2 "Develop Motivational Frames".

All four of the integrative multi- and interdisciplinary approaches discuss expanding on the selected theoretical models (or constructs), BCTs, standards (recommendations or codes of practice) and gamification strategies by translating and operationalising them into app design features. The way in which intervention components are conceptually operationalised into app design features needs to align with the preferences of the target population group. According to Approaches #18 and #20, users' preferences can be identified by reviewing literature, meta-

analyses and findings from empirical studies, and by conducting primary qualitative studies with target user representatives (using methods such as focus group discussions and surveys). The tasks involved in translating and operationalising components essentially entails conceptually designing how the mHealth app's main features and graphical user interfaces will be instantiated. The matrices and tables from Activity 2.2 can be extended by including a column to the far right, clearly articulating and explaining how each component will be operationalised as an app design feature. Approach #17's DHI Taxonomy can be utilised to identify and select persuasive system design principles (or persuasive strategies) for designing the app's software design features. Examples of persuasive design principles cover four categories: primary task support; dialogue support; system credibility support; and social support. Examples of persuasive strategies commonly employed within the mHealth physical activity app context include: self-monitoring; simulation; tailoring; reminders; praise; rewards; suggestions; social cooperation; social competition; social recognition; expertise; and trustworthiness. On another note, Approach #18 suggests developing conceptual designs in the form of screen mock-ups and graphical illustrations. In addition to graphical support materials, Approach #19's Component 2.2 "Specification of Interaction (Micro Level Persuasion)" recommends creating design rationale, design scenarios, requirements and claims specifications, and use case diagrams and narratives; all of which provides the team with a means of explicitly articulating their decisions and justifications when translating and operationalising intervention components into app design features. Design rationale offers a theory- and evidence-based reasoning for the team's conceptual design decisions. Design scenarios provide a short storyline describing how a user or persona interacts with and navigates through the app's design features. Requirements and claims specifications outline the app's main functionalities and features, the app's hardware (technical) and software (interface) requirements, and the claims supporting the specified requirements. The use case diagrams and narratives provide the team with sequenced graphical representations and descriptions for how users are intended to interact with the app's design functionalities and features. Moreover, Approach #20 suggests the team develop "Motivational Frames" for the mHealth app's conceptual design. A motivational frame, according to Approach #20, offers an underlying latent motivational structure for a cluster of BCTs (or theoretical constructs) that taps into more functional processes of health behaviour change intervention. In the context of mHealth apps for promoting physical activity behaviour change, Approach #20 developed three main motivational frames, including a "social" frame, a "cognitive" frame, and an "emotional" frame; each of which operates via an alternate underlying motivating process

structure. These motivational frames are considered as conceptual design options for the subsequent concrete design of the mHealth app (in *Step 3*).

Approach #17 offers an additional contribution with some the tasks discussed in its process's Step 3 which specifies "Designing" the intervention's "Characteristics and Workflow". This contribution draws on the BIT Model (Approach #7) and is not considered by the other three integrative multi- and interdisciplinary approaches. The tasks involved in designing the characteristics of the mHealth app intervention are aimed at defining how the components (BIT elements) are translated and operationalised into technical app design features, taking into account users' interactions and engagements with the digital device. Approach #17's DHI Taxonomy (Toolbox 2) identifies six key technical characteristics relevant to design features for the smartphone app platform, including: medium, complexity, aesthetics, personalisation, social role, and trustiness. In addition to the technical characteristics, Approach #17 emphasises the importance of creating a conceptual design workflow for the mHealth app intervention. The workflow refers to the set of rules that determine when and under which conditions each component (BIT element) is delivered to an individual user over time, taking into account various intervention and context-in-use changes. The concept of a workflow leverages off theory on Just-In-Time-Adaptive Interventions (JITAIs) (Mohr, et al., 2014). Example workflows identified by Approach #17 as applicable to the mHealth physical activity app context comprise: time-based workflows (for example, a reminder at 17h00 to walk); task-based workflows (for example, to walk 10 000 steps per day); and event-based workflows (for example, a reminder after two hours of physical inactivity or sedentary behaviour). The time-based workflow option is generally the easiest, whereas the two latter options are more challenging as they require automatic or manual user input to function effectively. The defined characteristics and workflow(s) can then be added to the translations and operationalisations for the mHealth app's conceptual design. These details can be used to inform a succinct summary for Activity 2.3 by completing items seven to nine under the third "Designing" category on Approach #17's TUDER Checklist, which helps provide the team with a clear and concise shared point of reference as to how the strategies, characteristics and workflow(s) of the intervention will be designed, translated and operationalised into app design features.

Overall, *Step 2* has comprised three activities: *Activity 2.1*, *Activity 2.2* and *Activity 2.3*. The output of *Step 2* is a conceptual design solution for the mHealth behaviour change app. This conceptual design includes a consolidation of: a clear definition for the performance and

change objectives; an explicit description for the mHealth app's theoretical base, BCTs, evidence-based standards, gamification strategies, and persuasive design principles; and a clear articulation for how these elements will be translated and operationalised as instantiated app design features, along with their technical characteristics and workflow(s). To support the productive and successful completion of activities and tasks in *Step 2*, the multi- and interdisciplinary team should be guided by formalised documentation outlining each team member's roles, contributions, responsibilities and decision-making powers, and the processes applied to navigate the team's communications and collaborations.

### *Step 3*

Once a design solution has been conceptualised in *Step 2*, the multi- and interdisciplinary team transitions to *Step 3*, where attention shifts towards designing, developing and prototyping a more concrete materialisation of the mHealth behavioural change intervention app. This stage involves iteratively designing-testing-refining an mHealth app's material design through a series of prototyping cycles, followed by a succession of pilot testing cycles. The outputs of the prototyping cycles can be referred to as minimum viable products (MVPs), and the final resulting output of *Step 3* is a fully fledged, functional and working mHealth intervention app prototype that is ready for large-scale studies and full deployment and implementation. In comparatively reviewing and analysing the four integrative multi- and interdisciplinary approaches, activities pertaining to app prototyping and pilot testing occurs in: Approach #17's Step 4 "Evaluating and Refining (the Intervention Design)"; Approach #18's Step 7 "User Testing and Developing the Final App Product"; Approach #19's Component 3 "Evaluation", comprising Component 3.1 "Evaluation of Intervention (Micro Level Persuasion)" and Component 3.2 "Evaluation of Intervention (Macro Level Persuasion)"; and in Approach #20's Step 3 "Target Population Assessment and Prototype User Experience Piloting" and Step 4 "Develop Functional Prototypes". Notably, a critical analysis and examination employing cognitive thought trials and judgement-making processing reveals two of the four integrative approaches (Approaches #17 and #19) to entangle formative evaluation activities with summative evaluation activities. In sharp contrast to many of the multi- and interdisciplinary approaches in the other three (Health Sciences, Information Systems/Technology, Partnership) categories, this entwinement is a noteworthy limitation and weakness of these two integrative approaches. Given this critical issue, this discussion actively undertakes to disentangle and clarify differentiations between activities relevant to prototype testing, pilot testing and

summative evaluation studies, the latter of which falls into *Step 4*. Dissimilarly to Approaches #17 and #19, Approach #20 distinguishes between formative and summative evaluation trials. Contrarily to these three integrative multi- and interdisciplinary approaches, Approach #18 fails to discuss and incorporate any of the activities applicable to conducting summative evaluation studies.

To commence tasks pertinent to *Step 3*, the team begins by developing a low-fidelity app prototype, often in the form of user interface screen mock-ups, wireframes, sketches, storyboards, and mock-ups illustrating the key app design features and the initial presentation of the intervention's main strategies (components), characteristics and workflow. Approach #20 suggests the team utilise brainstorming and other creative techniques to support them in creating a series of progressively improved low-fidelity app prototype versions. Over a short period of time, the fidelity of the prototype is revised and enhanced, resulting in a medium fidelity prototype, which can be used to initiate the iterative design-test-refine cycles with a sample of participants representing the target population group. All four integrative approaches recommend conducting these cycles by applying usability, heuristic user interface and user experience design testing methods. Approach #17 also mentions using think-aloud techniques and cognitive walkthroughs, while Approach #19 makes reference to human-in-the-loop testing, simulations and prototype run-throughs. The common aim shared by these methods is to elicit and gather users' feedback regarding their thoughts, feelings, experiences and opinions during their interactions with or after their interactions with the various iteratively-refined prototype versions. Approach #18 also recommends that users provide feedback on the acceptability, feasibility, engagement and potential effectiveness of the app prototypes. This user feedback can also be measured in terms of flow (user attention focus and user enjoyment) and usage (frequency, navigation, duration and depth of engaged and active interaction) (Approach #18). Approach #19 explains that the quintessential purpose of these iterative design-test-refine prototyping cycles is to assess and validate the claims, specifications, requirements, theoretical base, logic (program) model, design features, functionalities and intervention components of the app. Approach #19's Component 3.1 describes these activities as occurring on a "Micro Level [of] Persuasion" which focuses primarily on the "Interaction" and "Microsuasion" of the mHealth app prototypes (Blanson Henkemans, et al., 2015, p.56).

Although prototype testing generally involves a sample of participant users as representatives of the target population group, Approach #20 also discusses testing the app prototype versions

with experts and specialists who hold knowledge, skills and experience in the fields of usability, user interface design, user-centred design, user experience design, information systems design, and human-computer interaction. Approach #18 further recommends that the multi- and interdisciplinary team collaborate with experienced game designers and mobile app designers, as consultants from the gaming and smartphone app industries. Testing methods would therefore extend to include expert-orientated techniques, such as expert reviews. Approach #20 mentions the value experts can contribute when testing and improving the technical and design features and functionalities of the app prototypes, particularly with regard to the GPS, accelerometer, push notifications, user profiler, social networking links, the software app operating system standards, and more.

After a series of iterative design-test-refine cycles, the medium-fidelity prototype develops into a high-fidelity functional and working prototype that can be pilot tested with a representative sample of target user participants in a specific defined context. Generally, the medium-fidelity prototyping should occur over a short span of time, such as one to three weeks; whereas piloting with high-fidelity prototypes can run over one month (Smith, et al., 2016), several weeks, or perhaps even up to three months (Verbiest, et al., 2018). Piloting aims to gather users' feedback on the same assessment criteria as prototyping, including users' thoughts, feelings, experiences, opinions and suggestions regarding the app's acceptability, usability, user experience, feasibility, adoptability and engagement. These factors pertain predominantly to an information systems perspective of the mHealth app. The value in conducting piloting studies, and not only prototype testing, is to evaluate the potential effectiveness of and users' adherence to the intervention and its components (strategies), in addition to the app's design, appearance and interactivity outside of the laboratory context (with fully controlled variables). This opens evaluation to incorporate the health sciences perspective alongside the information systems perspective. The somewhat longer time frame (one to three months) also allows the team to measure the functional mHealth app prototype as a whole, particularly with regard to its short-term sustainability, adherence, engagement and user experience; thus providing a predictive indicator for the app's potential long-term usage and effectiveness and whether it achieves the defined objectives. To pilot test the functional prototype as realistically as possible, Approach #17 mentions using the pilot field study method which allows the team to observe and gather data outside of the laboratory or workplace environments, in real-world settings, with a particular group of participants in a particular context. Approaches #18 and #19 also refer to conducting focus groups, surveys, questionnaires and interviews with participant

users to supplement the piloting studies. Furthermore, Approach #19 briefly touches on assessing intermediate outcome (impact and effect) measurements that result from users' engagements with the app intervention and each of its specific components (strategies). Approach #19 suggests creating effect scorecards, concisely stipulating the claims, (intended) effects, and positive and negative outcomes. Two examples of effect scorecards can be referred to in Approach #19 (Blanson Henkemans, et al., 2015, p.54). Gaining an understanding of negative outcomes, as brought up by Approach #19, can help provide the team with insight into any potential unintended adverse consequences or trade-offs that can result from engaging with and using the intervention app.

Overall, prototype testing and subsequent piloting testing is often an iterative process, whereby each cycle aims to continuously refine and improve the app prototype over time until a full working "Functional" (Approach #20, Step 4) "Final App Product" (Approach #18, Step 7) is developed. At this stage, the final app product is available for public commercial release (full deployment and implementation) on consumer app markets such as the Android Google Play and Apple iOS app stores, and is ready for the team to conduct large-scale randomised controlled trials; therefore, progressing from *Step 3* to *Step 4*.

### *Step 4*

During *Step 4* the team shifts their focus to performing summative evaluation studies on the public, commercially released mHealth behaviour change intervention app. As discussed in *Step 3*, formative evaluation activities and summative evaluation activities are entangled in Approach #17's Step 4 "Evaluating and Refining (the Intervention Design)", and in Approach #19's Component 3 "Evaluation", comprising Component 3.1 "Evaluation of Intervention (Micro Level Persuasion)" and Component 3.2 "Evaluation of Intervention (Macro Level Persuasion)". Only the relevant summative evaluation details are extracted and incorporated in the activities discussed here in *Step 4*. Approach #20, together with its subsequent supplementary mHealth physical activity app case application paper publications (King, et al., 2013; 2016), covers summative evaluation activities in the last step of its process, Step 5 "Evaluate and Refine Functional Prototypes". In comparison to Approaches #17, #19 and #20, Approach #18 does not mention tasks pertaining to summative evaluation studies.

A critical comparative analysis of Approaches #17, #19 and #20 [together with King, et al. (2013; 2016)] reveals all three as performing randomised controlled trials (RCTs) for

summative evaluation studies. The shared primary aim of these trial studies is to measure and determine the clinical health and behavioural outcomes in relation to the app intervention's goals and objectives. These critical measures of performance are described by Approach #19 as aiming to evaluate the effect and impact of the intervention; that is, to determine whether the mHealth behavioural change intervention app is working as initially intended. According to Approaches #17, #18 and #20, the effect and impact outcomes can be measured in terms of anthropomorphic and health-related changes (such as BMI, weight, body fat percentage and waist-to-hip circumference ratio), behavioural changes (for example, accelerometer-derived increased walking and reduced sedentary behaviour) and quality of life changes (via assessment). These represent objective outcome measures, although subjective self-report measures (for example, the ecological momentary assessment and questionnaires) can also be informative (King, et al., 2013; 2016), yet are often criticised in the health sciences field as inflated, biased and unreliable (Urda, et al., 2017; Chastin, et al., 2018). The shared secondary aim of these trial studies is to measure and determine users' experiences with the mHealth app, particularly in terms of usability, acceptance, adoption, feasibility, usage, engagement and user satisfaction. Similarly to the methods and techniques used in *Step 3*, these studies aim to evaluate the digital and interactive aspect of the app, particularly with regard to its design features, aesthetics and technical functionalities. Also akin to *Step 3*, there exists a range of objective and subjective methods and techniques from which the team can select the most suitable option(s) in light of the intervention project at hand. However, the key difference between the assessment and outcome measures obtained in *Step 3* and *Step 4* is related to time and sustainability. Since RCTs are generally conducted over an extended period of time, the team can evaluate engagement, usage, experience and adherence over a more sustainable timeframe. Approach #18, although failing to specify a particular summative evaluation step in its process, does make brief reference to leveraging the power of data and game analytics as a means to tracking, recording and monitoring users' patterns and activities with the mHealth app intervention as a whole, or with particular components (strategies) and/or specific design features and functionalities of the mHealth behavioural change intervention app.

Essentially, as similarly touched on in *Step 3*, Approach #19 describes the summative evaluation process as aiming to assess and validate the claims, specifications, requirements, theoretical base, logic (program) model, design features, functionalities and intervention components of the final app product. In other words, summative evaluations should aim to evaluate the mHealth app from both a health sciences perspective and an information systems

perspective; thereby assessing, measuring and determining the effectiveness and impact of both the health behavioural change intervention and the app (as a digital platform), respectively. Furthermore, Approaches #19 and #20 mention using methods such as focus groups, semi-structured interviews, questionnaires and surveys to supplement the RCTs. Given the limitations and criticisms of RCTs in mHealth behaviour change app intervention research, alternative summative evaluation methods are discussed by two of the four integrative multi- and interdisciplinary approaches. Approach #17 references the Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018) and the Sequential Multiple Assignment Randomised Trial (SMART) method (Collins, Murphy and Stretcher, 2007), and Approach #19 mentions using the quasi-experimental design trial method.

Overall, Approaches #17, #19 and #20 discuss the results and findings from the summative evaluation studies as being used to further inform future refinements, improvements, advancements and updates to the commercially released mHealth behaviour change intervention app. Approaches #19 and #20 also highlight the importance of consistent tracking, documenting, monitoring and reporting throughout the lifespan of the deployed mHealth app, and Approach #17 suggests completing items ten and eleven on the TUDER Checklist's fourth category "Evaluating and Refining", which helps provide the team with a succinct and concise shared point of reference concerning the study designs and results of the summative evaluation studies. On a final note, Approaches #17 and #20 emphasise the importance of actively involving all of the multi- and interdisciplinary team members in the summative evaluation process, particularly since each member is able to offer an alternative perspective, knowledge, skills, experience, insight, suggestions and contributions to the holistic design and effectiveness of the mHealth behaviour change intervention app.

#### *Summary of Process Steps and Activities: Integrative Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.4.4, Figure Appendix I.7 provides a summarised high-level graphical illustration of the key themes and subthemes identified in the process steps (and activities) of the four multi- and interdisciplinary approaches in the Integrative Perspective category.

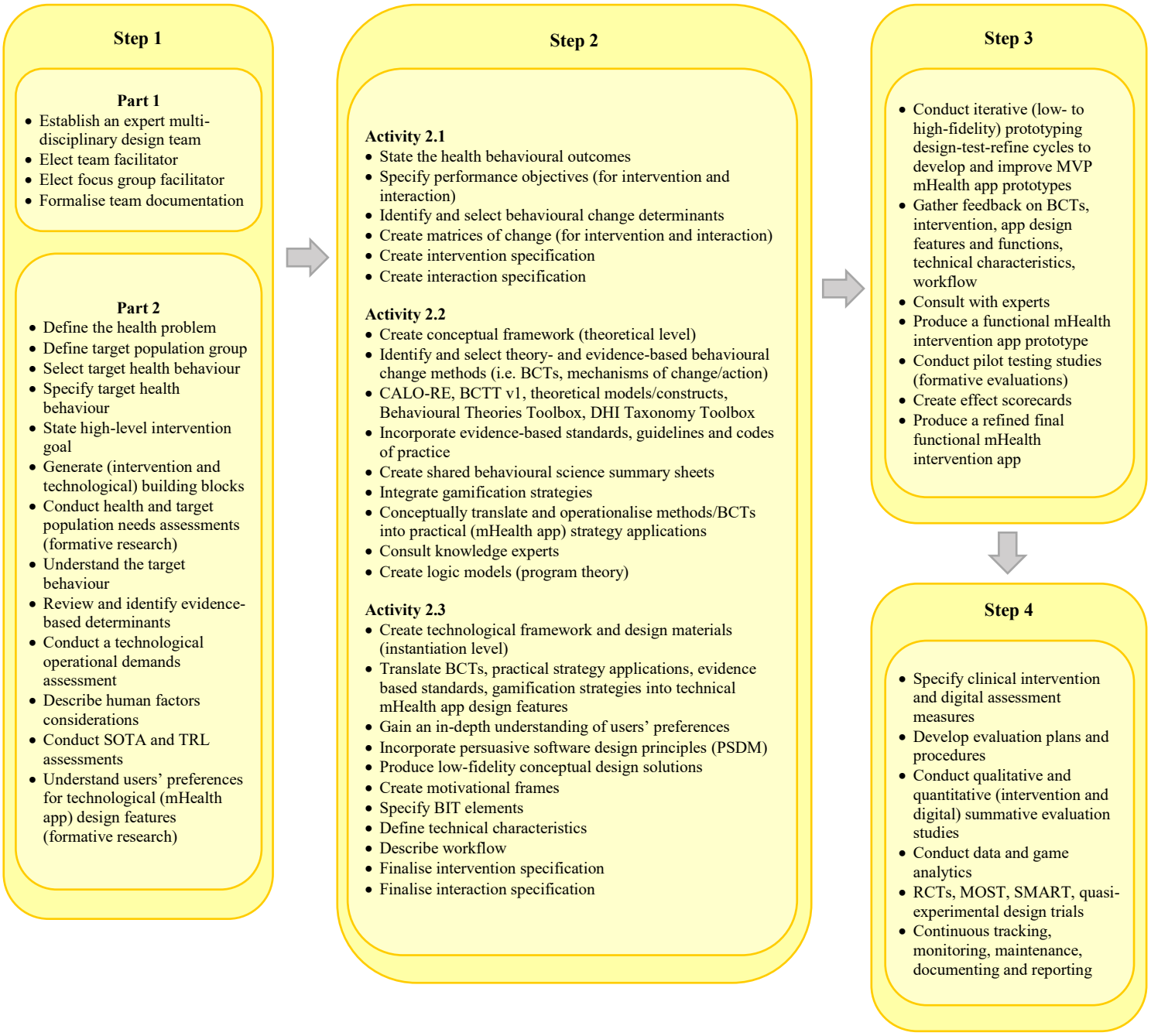



*Figure Appendix I.7: Summary of Process Steps for Multi- and Interdisciplinary Approaches: Integrative Perspective Category [Researcher's own construction]*

### 6.4.4.5 Design Artefacts, Boundary Objects and Supporting Methods

*Step 1*

The first part of *Step 1* involves establishing and formalising a multi- and interdisciplinary team. The main outputs from this initial aspect of *Step 1* include: a multi- and interdisciplinary team document and contract (outlining each team member's disciplinary background, their contributions in terms of knowledge, skills, expertise and activities, and their powers of team status, influence and decision-making); a specification outlining the details of the multi- and

interdisciplinary team leader, the focus group facilitator and their assistant (Approach #18); a report clearly specifying consensus terminology and shared definitions; team protocols and procedures; team meeting procedures; team communication platforms (for example, emails, skype and google hangouts); collaborative work practice guidelines (detailing the team members' roles, responsibilities, involvements and coordinated activities).

The second part of *Step 1* aims to understand and define the health problem space, which covers the health problem, the target health behaviour, the health behavioural outcome(s) and the target population group. Approach #19 refers to this as a (health and at-risk target population) needs assessment. The main input methods the team can utilise to gain a deeper understanding of the problem space are: reviews of literature; reviews of meta-analyses; reviews of epidemiological studies; reviews of published empirical studies; and primary qualitative (formative) research methods (which are performed with target population representatives, using methods such as focus groups, interviews, workshops, questionnaires and surveys). Whether primary or secondary methods are used, the team should aim to produce a needs assessment that is informed by a better understanding of the health problem, the target health behaviour, the health outcomes, the target population group (including their characteristics, current state of wellbeing and quality of life), and the evidence-based causal at-risk factors and determinants of behaviour change for the defined target group. The Logic Model of the Problem (Approach #1) can also be referred to as an input to diagrammatically illustrate the health problem space. While the needs assessment and Logic Model of the Problem (diagram) generally adopts a health sciences perspective, Approach #19 suggests using other artefacts, objects and methods to gain a deeper understanding of the technological perspective, with the aim of producing an operational needs (or operational demands) assessment, including inputs such as: human factors design theory, principles and method guidelines; technological state-of-the-art (SOTA) assessment guidelines; the technology readiness level (TRL) model; as well as reviews of literature, empirical studies and existing digital technologies (such as smartphone apps) and primary qualitative and quantitative (formative) research methods (such as focus groups, interviews, questionnaires, surveys and workshops).

The main outputs for the second part of *Step 1*, from predominantly a health sciences perspective, include: a statement of the health problem (in behavioural terms) and its context; a specification of the targeted health behaviour; a broad high-level statement for the intervention aims; a statement of the intended health behavioural outcomes; a statement of the

selected target population group; a health and at-risk target population needs assessment (covering the health problem in relation to the target population groups' demographics, characteristics, current state of wellbeing, quality of life and prevalent health conditions, and associated evidence-based determinants); a Logic Model of the Problem (diagram); and a list of influential theory- and evidence-based determinants. An integration of the information systems perspective together with the health sciences perspective produces additional outputs for the second part of *Step 2*, including: an operational needs (or operational demands) assessment (covering the characteristics, roles, tasks and contexts pertinent to the target users' work, processes and activities, and the work and activity conditions for target users interacting with the digital health behaviour change intervention); human factors design, principles and methods finding report; a technological state-of-the-art (SOTA) assessment report; and a technology readiness level (TRL) assessment report. Furthermore, Approach #18 emphasises producing specification outlining users' mHealth app design feature preferences, leading to additional outputs including a user BCTs preferences table (identifying intervention component/strategy themes and sub-themes that are important to the target population group), and a user app design features preferences table (identifying app design feature and appearance themes and sub-themes that are important to the target population group). Lastly, the first three checkboxes in the first category ("targeting") of the TUDER Checklist can be confirmed and checked.

### *Step 2*

*Step 2*'s aims are divided amongst three main activities: *Activity 2.1* (to outline the mHealth intervention app's performance and change objectives), *Activity 2.2* (to develop a theoretical base for the intervention of the mHealth app), and *Activity 2.3* (to translate, operationalise and instantiate the theoretical base into a conceptual mHealth intervention app design solution). To carry out *Activities 2.1* and *2.2* in *Step 2,* valuable input methods mentioned by all four partnership approaches include literature reviews, meta-analysis reviews, and reviews of findings from empirical studies. These input methods contribute to informing the development of a sound theoretical base as they allow the team to review and identify a variety of theory- and evidence-based intervention strategies (BCTs), evidence-based standards, guidelines and codes of practice, gamification strategies (techniques), and persuasive system design strategies. Further valuable input methods are expert consultations (in the form of focus groups or expert reviews) and primary quantitative and qualitative empirical studies (such as focus groups and

surveys) with target population representative participants. In addition to these input methods, other theoretical input artefacts that are useful for informing the creation of a theoretical base include evidenced-based theoretical models (for example SCT, TTM, HAPA, the ASM Model, and the Zone of Proximal Development), and theory- and evidence-based gamification models. Furthermore, other useful input artefacts and objects that can act as boundary objects for the heterogeneous team members include: Approach #17's Toolbox 1 (which identifies and describes key individual and (primary)interpersonal health (psychology) behavioural theories); Approach #17's Toolbox 2 (the DHI Taxonomy); the 40-item CALO-RE Taxonomy (Michie, et al., 2011); the BCTT v1 93-item hierarchically clustered taxonomy (Michie, et al., 2013); the Persuasive Systems Design Model (Oinas-Kukkonen and Harjumaa, 2009); Approach #20's templates for "Behavioural Science Summary Sheets" (also referred to as "Cheat Sheets").

The main outputs for *Activities 2.1* and *2.2* in *Step 2* include: a specification of the mHealth intervention's key aims and objectives; a specification of the performance objectives; a specification listing the change objectives; a list of selected determinants (along with descriptions and justifications for selection); a Matrix of Change table for the intervention level (mapping performance objectives, determinants and change objectives for the intervention) (Approach #19); a Matrix of Change table for the interaction level (mapping performance objectives, determinants and change objectives for the mHealth app's interactions); a list of selected gamification strategies and techniques; a list of selected persuasive system design features (strategies); a list of selected theoretical models and constructs underpinning the intervention's theoretical base (along with descriptions and justifications for each selection); a list of referenced and employed evidence-based standards, guidelines and codes of practice (such as the WHO's physical activity recommendations); Behavioural Science Summary Sheets; a list of any reviewed existing commercial smartphone apps; and an overall Logic Model of the mHealth app's theoretical base design (Approach #18). Furthermore, the fourth to sixth checkboxes in the second category ("understanding") of the TUDER Checklist can be confirmed and checked.

To carry out *Activity 2.3* the same input methods (used for the theoretical base) are also useful and informative for translating the theoretical foundations into conceptual and practical design solution elements for the mHealth app design features, technical characteristics and workflow. These inputs methods include reviews of the existing knowledge base, existing similar mHealth

apps, and primary quantitative and qualitative empirical studies (such as focus groups and surveys) with participants as sample representatives of the target population group. When employing these methods, Approaches #18 and #20 stress focusing on what users' preferences are for how the mHealth app's design features will be operationalised and instantiated in the conceptual design solution, particularly since this impacts the app's interactivity, usability, user experience, engagement, acceptance, adoption, adherence and long-term usage and effectiveness. In addition to these input methods, other boundary artefacts and design objects that are useful for creating operationalising and instantiating the theoretical base into a conceptual mHealth app design solution include: Approach #17's Toolbox 2 (the DHI Taxonomy); the Taxonomy of Behaviour Change Methods (TBCM) (which provides parameters for application) (Kok, et al., 2016); the Persuasive Systems Design Model (which provides operationalised app design feature examples) (Oinas-Kukkonen and Harjumaa, 2009); gamification models; just-in-time-adaptive intervention models; and guidelines proposed by the BIT Model (Approach #7); motivational frame guidelines (Approach #20); UML modelling techniques and software; guidelines for creating a specification for the mHealth intervention app's interaction (Approach #19).

The main outputs for *Activity 2.3* in *Step 2* include: documentation reporting on the findings from reviews (on literature, empirical studies and similar existing commercial mHealth apps); documentation reporting on the procedures and findings from conducting primary qualitative and quantitative studies with participants; a user app design features preferences table (identifying app design feature and appearance themes and sub-themes that are important to the target population group); a BCT-Practical Strategy Application matrix (table); a BCT-Practical Strategy-Operationalisation matrix (mapping the selected BCTs, gamification and persuasive techniques to operationalised and instantiated mHealth app design features); a specification for the interaction microsuasion level (Approach #19); design rationale (justifying decisions for operationalisations); design scenarios (providing short storylines for user personas); a requirements and claims specifications report (outlining the mHealth app's requirements and the supporting claims); use case models (diagrams) and narratives; a report on the motivational frames (outlining and describing the latent motivational structure and functional processes). Furthermore, additional outputs from *Activity 2.3* based on the BIT Model (Approach #7) guidelines include: a report on the BIT elements (identifying, describing and justifying each element's selection and operationalisation); a report on the mHealth app's technical characteristics (outlining, mapping and elaborating on the operationalisation of BIT

elements into technical features); a workflow specification (describing the sets of workflow rules) and a workflow graphical representation (diagram) (specifying and illustrating the BIT elements, technical characteristics and transitional and delivery flows to an app user over time); as well as a specification on any selected and operationalised just-in-time-adaptive intervention techniques. Moreover, seventh to ninth checkboxes in the third category ("designing") of the TUDER Checklist can be confirmed and checked, which provides the team with a clear and concise shared point of reference as to how the strategies, characteristics and workflow(s) of the intervention will be designed, translated and operationalised into app design features. Overall, the key main boundary object output for *Step 2* as a whole is a theoretical and conceptual design solution for the mHealth behaviour change intervention app, which will be utilised by the team going forward to create a tangible mHealth intervention app.

### *Step 3*

The outputs from *Step 2* together with other artefacts, objects and methods are employed in *Step 3* to translate the theoretical and conceptual design solution into a tangibly concrete and material mHealth behaviour change intervention app prototype. To perform the iterative series of design-test-refine prototyping cycles, the team can employ prototype development and testing methods, techniques and guidelines. To create low-fidelity prototypes, input materials can include paper, cardboard, whiteboards, pens, colour materials, and modelling boards, amongst others. These materials can be utilised together with creative and expressive input methods such as brainstorming, six thinking hats and divergent thinking. Over time, low-fidelity prototypes are developed into medium-fidelity prototypes using input prototype testing methods including: usability testing; human-computer interaction testing; user interface design testing; user experience design testing; think-aloud techniques; cognitive walkthroughs; human-in-the-loop testing; and prototype run-throughs. As the team transitions towards developing and refining a high-fidelity mHealth app intervention prototype, input methods can begin to include the use of computer-aided design software; simulation software; 3D modelling software; and interactive working app software prototypes installed and tested on smartphone devices. Although many prototype testing sessions are generally run with sampled participants as representatives of the target population group, Approaches #18 and #20 suggest that the team can also conduct primary empirical studies with knowledgeable and experienced experts and specialists from various heterogeneous disciplinary backgrounds (such as designers and developers from the gaming, smartphone app and physical activity/exercise industries), and

can employ input methods such as focus groups, expert discussions and expert reviews and interviews.

The main prototyping outputs at the early stages of *Step 3* include: low-fidelity prototypes (for example user interface screen mock-ups, wireframes, sketches, storyboards, and mock-ups illustrating the key app design features and the initial presentation of the intervention's main strategies/BCTs, BIT elements, characteristics and workflow). The main prototyping outputs at the latter prototyping stages of *Step 3* include: medium- and high-fidelity prototypes (from prototype simulations to fully functional and working mHealth app prototype versions). At both the earlier and latter stages of *Step 3* the team creates prototyping outputs including: documentation reporting on all of the iterative low-, medium- and high-fidelity prototyping cycles (specifying and justifying refinements over time); documentation providing detailed reporting on the findings from the prototype testing sessions (with target participants users or experts/specialists), along with the study designs, procedures and ethical approvals.

Subsequent to the prototype testing stage, the team can employ pilot testing methods as inputs for measuring and assessing the mHealth app from both a health sciences perspective and an information systems perspective. The input method for pilot testing generally includes the pilot field study method (which occurs outside of the laboratory, in real-world settings), and supplementary input methods can include focus groups, surveys, questionnaires and interviews. The measures utilised in these input methods from the two overarching perspectives would on the one hand relate to users' adherence to and the potential effectiveness and impact of the intervention and its constituting components (strategies/BCTs), and on the other hand, relate to the mHealth app's design features, usability, user experience, acceptance, usage, engagement and persuadability. The main outputs from pilot testing studies include: documentation reporting on the findings from the pilot testing studies (outlining the study designs, procedures and ethical approvals); a report tracking and documenting any additional refinements and improvements to the mHealth app post-pilot testing; effect scorecards concisely reporting on the claims, intended effects, positive outcomes and negative outcomes (unintended adverse consequences or trade-offs) from the pilot studies.

On another note, Approach #19 emphasises the importance of creating and producing boundary objects and design boundary artefacts that can be used by all of the collaborating multi- and interdisciplinary team members together. Examples of these knowledge and design boundary objects include: a glossary (providing a common terminological syntactic and semantic

language with mutually agreed-upon interpretably flexible definitions); a shared concept map (providing a common ideation and design for the macro and micro persuasion levels); a standardised and shared ontology or ontologies (specifying common taxonomies for supporting and facilitating cross-disciplinary team communications, negotiations and teamwork); and shared mutually-developed user scenarios and design scenarios (which provides the team with a common conceptualisation, articulation and graphical representation of the mHealth behaviour change app intervention and how users are intended to interact with and use the app). All in all, the key outputs from *Step 3* are the several iterations of minimum viable products (MVPs), mHealth intervention app prototypes, and pilot-tested prototypes; however, the most important output from *Step 3* overall is a fully fledged, functional and working mHealth intervention app that is ready for large-scale studies and full deployment and implementation.

### *Step 4*

The key outputs from *Step 3* together with other summative evaluation artefacts, objects and methods are employed in *Step 4* to assess and determine the effectiveness of the mHealth behaviour change intervention app. Approaches #17, #19 and #20 [together with King, et al. (2013; 2016)] all use traditional gold standard randomised controlled trials (RCTs) as the main input method for conducting summative evaluation studies. Other randomised experimentation and trial summative evaluation input methods include: Multiphase Optimisation Strategy (MOST) method (Collins, et al., 2005; Collins, Murphy and Stretcher, 2007; Collins, 2018); the Sequential Multiple Assignment Randomised Trial (SMART) method (Collins, Murphy and Stretcher, 2007); and the quasi-experimental design trial method (Approach #19). The objective outcome measures utilised with traditional RCTs and randomised trial experiments include: anthropomorphic and health-related changes (such as BMI, weight, body fat percentage and waist-to-hip circumference ratio), behavioural changes (for example, accelerometer-derived increased walking and reduced sedentary behaviour) and quality of life changes (via assessment). In addition to objective input measure, an example of a subjective self-report measure is the ecological momentary assessment and questionnaire. Since traditional RCTs and randomised trial experimentation summative evaluation methods generally adopt a health sciences perspective, the team can also employ other evaluation methods that can assess and measure the technological and information systems perspective. An example of a valuable technological input method includes data and game analytics

software (such as Google Analytics for Mobile Apps), and additional supplementary methods include focus groups, semi-structured interviews, questionnaires and surveys.

The main outputs from *Step 4* include: documentation reporting on the details of the summative evaluation studies applied (including the study designs, participant particulars, study protocols and procedures, et cetera); reports on the results and analysis findings from the primary empirical summative evaluation and trial studies; applications and documents with proof of ethical approvals; documentation reporting on the details of the supplementary primary empirical studies (including the study designs, participant particulars, study protocols and procedures, et cetera); documentation reporting on the results and findings from the supplementary primary empirical studies (such as focus groups, semi-structured interviews, questionnaires and surveys); data analytics reports; game analytics reports; monitoring and maintenance reports (Approach #18); process evaluation reports (Approach #19); effect and impact reports (Approach #19); and a multi- and interdisciplinary team document reporting on and summarising all of the large-scale trial evaluation decisions made throughout *Step 4*. Furthermore, the team can confirm and check the tenth and eleventh checkboxes on the TUDER Checklist's fourth category "Evaluating and Refining", which provides the team with a succinct and concise shared point of reference concerning the study designs and results of the summative evaluation studies.

### *Summary of Summary of Design Artefacts, Boundary Objects and Methods: Integrative Perspective Category*

Based on the critical comparative and thematic analysis performed in Subsection 6.4.4.5, Figure Appendix I.8 provides a summarised graphical illustration of the key artefacts, design boundary objects and supporting methods identified as inputs and outputs into the process steps (and activities) of the four multi- and interdisciplinary approaches in the Integrative Perspective category.

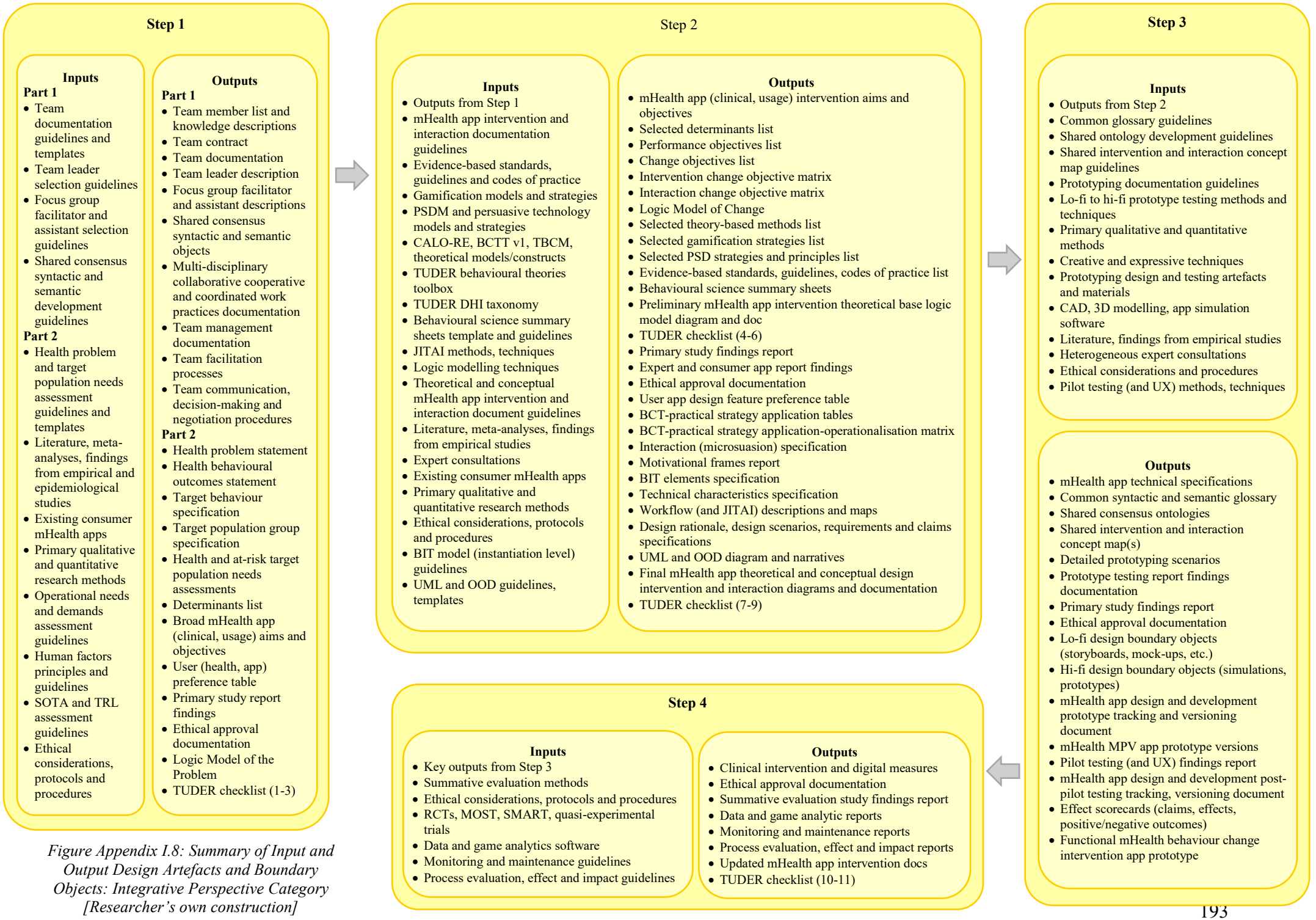



*Figure Appendix I.8: Summary of Input and Output Design Artefacts and Boundary Objects: Integrative Perspective Category [Researcher's own construction]*

#### 6.4.4.6 Knowledge Boundary Contributions

All four of the multi- and interdisciplinary approaches in the Integrative Perspective category latently and explicitly argue for the transfer, translation and transformation of knowledge across heterogeneous community of practice boundaries as a necessary and integral requirement for the enhanced design of smartphone mHealth (promotion) behaviour change intervention apps. A cross-comparison between the four approaches reveals Approaches #17 and #19 as contributing relatively more to the knowledge boundary analysis findings than Approaches #18 and #20. On the one hand, Approaches #17 and #19 overtly discuss differences and dependencies in the heterogeneous team members' diverse knowledge, skills, expertise, aims, interests and activities, and inherently argue for continuous cross-boundary team communication, collaboration, cooperation and coordination. On the other hand, Approaches #18 and #20's discussion on differences and dependencies and cross-boundary team communication, collaboration, cooperation and coordination is implicit, yet is identifiable through critical thought trials informed by a knowledge and object boundary lens. Approach #17, for instance, explicitly recognises the different philosophical viewpoints of BCTs and PSD principles, and their derivation from the fields of health science and health psychology, and the fields of persuasive technology, persuasive systems design and information systems, respectively. While acknowledging these differences, Approach #17 expressly argues that they "have some common elements… [despite that] they are used separately in many DHI [digital health intervention] studies". This common ground is fundamental for knowledge to be transferred, translated and transformed across different communities of practice. Furthermore, for heterogeneous team members to positively contribute to the enhanced design of mHealth behaviour change apps, common language, common meanings and common interests need to be established and actively employed throughout the intervention development process.

At a syntactic knowledge level, differences in the representation of knowledge and how language and terminology is stored, processed, transferred and retrieved is the point of focus. Standardised language artefacts and classification systems such as terminological glossaries and taxonomies are examples of syntactic knowledge boundary objects. Approach #18 and Approach #19 both discuss the creation and use of a common glossary between multi- and interdisciplinary team members without consciously recognising or articulating it as a grounding syntactic knowledge boundary artefact. Approach #18 describes the multi- and interdisciplinary design team members as brainstorming and establishing "key concepts and constructs" promptly after the team has been formalised, and suggests documenting the shared

glossary so that it can function as a common point of reference at all stages of the mHealth behaviour change app development process. Approach #19 expressly recognises the common glossary of "key concepts" and "terms" and associated definitions as "dealing with both technical [persuasive system] features and [health] behaviour change strategies", therefore integrating knowledge from two overarching fields into one commonly shared syntactic object (Blanson Henkemans, et al., 2015, p.50). Approach #19 also explains that a common glossary of key terms can be utilised to generate an ontology that the team can reuse for other digital health behaviour change intervention projects in the future. Furthermore, similar to Approach #17, Approach #19 explicitly discusses how a multi- and interdisciplinary team of health behaviour change intervention designers and developers "come from different fields" and that they "often speak different jargons" informed by their different perspectives and expertise (Blanson Henkemans, et al., 2015, p.54). In light of the "existing language barriers between developers from different disciplines", Approach #19 proposes its multi- and interdisciplinary approach as a "*lingua franca*" (that is, a "common language") that can be used to "bridg[e] the language gap… between the different fields involved in the development process" (Blanson Henkemans, et al., 2015, p.50, 55). Moreover, similar to Approaches #18 and #19's discussions on syntactic knowledge objects, Approach #17 proposes a multi- and interdisciplinary approach that incorporates a "unified DHI Taxonomy" (Toolbox 2) which integrates "two widely used taxonomies" (Wang, et al., 2019, p.4), namely the CALO-RE Taxonomy (Michie, et al., 2011) and the PSDM Principles (Oinas-Kukkonen and Harjumaa, 2009). Notably, although these two taxonomies (syntactic artefacts) originate from "different research [practice] communities" (Wang, et al., 2019, p.1) and are informed by "different philosophies" (Wang, et al., 2019, p.2), Approach #17 argues that the BCTs (from CALO-RE) and the PSD Principles (from the PSDM) share "some common elements" and therefore can be leveraged and integrated into "a more comprehensive taxonomy" (Wang, et al., 2019, p.2). A valuable contribution of Approach 17's integrated DHI Taxonomy is that it draws from two taxonomies that are frequently utilised and applied to the smartphone app and physical activity health (promotion) behaviour change intervention contexts. Most notably, the 40-item CALO-RE Taxonomy (Michie, et al., 2011), which was developed to target theory- and evidence-based determinants and actionable mechanisms for physical activity and healthy eating behaviour change in particular. In essence, syntactic artefacts (such as common languages, glossaries, ontologies and taxonomies) enable and facilitate knowledge transfer between multi- and interdisciplinary team members who hold different philosophical viewpoints and who originate from (and are localised within) different disciplines and communities of practice.

In progressing from the syntactic to the semantic knowledge boundary, the multi- and interdisciplinary team members can refer to and employ artefacts such as shared forms, templates and patterns, common methods and processes, and standardised guidelines and recommendations to translate knowledge across their heterogeneous community of practice boundaries. Approach #18, for instance, mentions the use of common standardised guidelines such as the British Standards Institution Code of Practice for Health and Wellbeing Apps. Approach #20 discusses the shared creation and use of "Behavioural Science Summary Sheets" which should utilise "lay terms" to facilitate common interpretations of meaning between experts from the fields of health behavioural sciences and user experience design (Hekler, et al., 2011, p.2). Furthermore, Approaches #17 and #19 discuss how different interpretations of meaning can "lead to misunderstandings" and that this hindered understanding can lead to impediments in the contributions offered by participating multi- and interdisciplinary team members (Blanson Henkemans, et al., 2015, p.54). Moreover, Approach #19 asserts that on the basis of its common language or *"lingua franca"* (at a syntactic level), its proposed multi- and interdisciplinary approach, when applied systematically, can be employed to "improve the communication and collaboration" between multi- and interdisciplinary design and development team members (at a semantic level) (Blanson Henkemans, et al., 2015, p.54). Approach #19's argument is legitimate in that an established common language at the syntactic knowledge boundary enables the progression towards common meanings at the semantic knowledge boundary as team members communicate, collaborate and cooperate regarding increases in novelties, dependencies and differences in interpretations of meaning. Approach #17's DHI Taxonomy, for instance, operates on both a syntactic and semantic knowledge level since it offers both a common language and common meanings for collaborating team members. For example, Approach #17 explains how sixteen of the principles from the PSDM "have the same or similar definitions with counterparts from the BCT Taxonomy", such as self-monitoring, competition, social comparison and tunnelling to name a few. Shared artefacts, methods and processes, such as Approaches #17 and #19, therefore provide common points of reference from which common meanings can be discussed, translated and established between heterogeneous team members. Put differently, semantic knowledge objects offer a means of "representing [and] learning about" differences and dependencies in knowledge (Carlile, 2002, p.453). Semantic boundary artefacts also facilitate and support communications around the drawing out and extracting of past experiences, implicit knowledge and expertise that otherwise would not have been explicitly articulated by collaborating members, yet are relevant and

necessary to state to foster the development of common meanings and understandings (Approach #19).

In transitioning from a semantic level to a pragmatic level, all four integrative multi- and interdisciplinary approaches discuss the creation and iterative refinement of prototypes as invaluable to the digital health behaviour change intervention development process. None of the four approaches, however, recognise prototypes as pragmatic design boundary objects that can be utilised by multi- and interdisciplinary teams to facilitate the transformation of knowledge and enable the generation of new design knowledge across heterogeneous intersecting and collaborating community of practice members. Approach #17 latently recognises the differences in interests and aims with regard to intervention objectives and digital mHealth app objectives, yet provides no guidance for negotiating around conflicts of interest. Approach #18 similarly fails to discuss conflicts of interest, although an implicit understanding is conveyed in the creation of common interests and common goals at a pragmatic knowledge level. Of the four integrative approaches, Approach #19 discusses and references pragmatic design knowledge artefacts the most frequently, albeit latently and not from a knowledge boundary or boundary object perspective. A critical review and analysis of the paper on Approach #19 reveals several examples of pragmatic design boundary objects that are utilised by the multi- and interdisciplinary design team to transform and negotiate design knowledge, including: design scenarios; design rationale; use case scenarios; use case diagrams; common concept maps; personas; requirements and claims specifications; software simulations; paper prototypes; user interface design mock-ups; intervention design mock-ups; low- to high-fidelity prototypes; and communal pictures. All of these design boundary artefacts provide multi- and interdisciplinary team members with concrete and tangible materials that enable, facilitate, mediate and support communications, negotiations and collaborations around informatic requirements and design work activities, and the transformation and generation of novel and innovative design knowledge at the pragmatic knowledge level. On another somewhat related note, none of the four multi- and interdisciplinary approaches in the Integrative Perspective category recognise or discuss power dynamics, decision-making processes and knowledge trade-offs, which all operate at the pragmatic knowledge boundary.

#### 6.4.4.7 Limitations and Lessons Learned

Limitations, gaps, weaknesses and lessons learned can be identified across all of the four multi- and interdisciplinary approaches in the Integrative Perspective category. The following short

discussion does not provide an extensive critical analysis on all possible limitations or lessons learned, but instead touches on a few noteworthy points given the adopted theoretical lens (boundary object perspective) utilised to frame the conducted cognitive thought trials and judgement-making processes. With this being said, a first glance cross-comparison of the four approaches reveals that they all offer insights and lessons in being particularised to the health promotion behaviour change intervention context. Associated with this contextual orientation is the selected mode, vehicle or platform through which a given health behaviour change intervention is intended for delivery. While Approaches #18 and #20 provide insights gained with their scoped focus to the smartphone (mHealth) app platform, Approaches #17 and #19 are comparably more limited in that their processes are generalised to many types of digital platforms and persuasive systems, respectively. Although, in recognising this relative weakness, Approaches #17 and #19's platforms encompass the smartphone app platform, and thus still offer insights applicable to this theoretical analysis. On a smartphone app platform-related note, Approaches #19 and #20 are limited in that they do not offer provide guidance for translating and operationalising intervention strategies (BCTs) into BIT elements and instantiated digital app design features. Approach #18 provides insights into operationalising and instantiating BCTs into mHealth app design features; however, Approach #17 comparably offers more lessons learned in that it incorporates the translation of BCTs into BIT elements, technical characteristics and workflows (inspired by Approach #7) before operationalising and instantiating strategies and techniques into mHealth app design features. Furthermore, all four approaches offer lessons learned in their orientations toward delivering health (promotion) behaviour change interventions at the dual intra-(primary)interpersonal level, and their prioritising of personal and social modifiable factors and determinants over broader external factors operating on organisational, community, national (societal) and supranational levels. On an additional note with regard to context, Approaches #17 and #20 provide further insights and lessons learned regarding their mHealth app intervention case applications, specifically: a physical activity and sedentary behaviour change app *SitCoach* (Wang, et al., 2017) (which employed Approach #17); and three different physical activity apps *Analytic (or Cognitive)*, *Social*, and *Affective (or Emotional)* (King, et al., 2013; 2016) (which applied Approach #20).

In terms of the nature of the integrative approaches, Approaches #18 and #20 offer insights into adopting iterative, rapid and cyclical approaches to the design, development and evaluation of mHealth behaviour change intervention apps. Approaches #17 and #20 also offer insights into performing iterative and cyclical processes, although their approaches are comparably

weaker in that their processes do not promote agile or rapid approaches. Related to the nature of the approaches are the perspectives they offer. Lessons can be learned from Approaches #18, #19 and #20 that consider commercial, product development and consumer market (industry) perspectives, which ties to a business perspective. Approaches #17, in contrast, is limited in that it does not consider a business-related perspective. Approaches #17 and #19 provide valuable lessons learned in their integration of persuasive technology and persuasive systems design perspectives. Approach #18 is limited in that it fails to incorporate a persuasive systems design perspective, but provides lessons learned in its integration of gamification and game design for mHealth behaviour change intervention apps. Approach #19 further offers insights in its grounding in Situated Cognitive Engineering (sCE) and its use of SOTA and TRL assessments, which provide additional lessons learned that Approaches #17, #18 and #20 fail to consider. Also related to the nature and perspectives of approaches are their proposed and prescribed steps, stages, components and activities. In terms of notable limitations, Approach #18 does not mention tasks pertaining to summative evaluation studies. On the contrary, Approaches #17, #19 and #20 [together with King, et al. (2013; 2016)] all utilise RCTs for summative evaluation studies. Yet, despite Approach #18's weakness in failing to incorporate summative evaluation activities, it does provide lessons learned in its brief reference to leveraging the power of data and game analytics (such as Google Analytics for Mobile Apps) as a means to tracking, recording and monitoring users' patterns and activities with the mHealth app intervention as a whole, or with particular components (strategies) and/or specific design features and functionalities of the mHealth behavioural change intervention app. In addition, Approaches #19 and #20 provide valuable insights in that they employ methods such as focus groups, semi-structured interviews, questionnaires and surveys to supplement the RCT summative evaluation studies. Furthermore, in acknowledging the frequent criticisms of traditional RCTs as impractical and unsuited to the mHealth app intervention context, Approach #17 provides lessons learned in referencing the employment of more recently proposed RCT-adapted studies, namely the Multiphase Optimisation Strategy (MOST) method, and the Sequential Multiple Assignment Randomised Trial (SMART) method; while Approach #19 suggests using the quasi-experimental design trial method. On a note associated with evaluations, all four integrative approaches are limited in that they fail to recognise the value in referencing standardised reporting guidelines such as the Consolidated Standards of Reporting Trials of Electronic and Mobile HEalth Applications and onLine TeleHealth (CONSORT-EHEALTH) statement and checklist, and the mHealth Evidence Reporting and Assessment (mERA) checklist.

On another note, all four integrative approaches are relatively time and resource intensive, particularly considering their processes aim to comprehensively integrate and bridge heterogeneous multi- and interdisciplinary knowledge and expertise contributions. This is a weakness but also insightful in that it implies the complexity associated with designing, developing and evaluating smartphone mHealth behaviour change apps cannot be overlooked or disregarded. In addition, in keeping with the mention of resource demands, all four approaches in the Integrative Perspective category are limited in that they require (and implicitly assume) all of the participating multi- and interdisciplinary team members to possess a sufficient, yet significant, amount of specialist knowledge, skill and expertise in order to interpret, make-sense-of, understand and apply the respective steps/stages and activities of their proposed processes. This implies a need for considerable past experience and substantial tacit knowledge and understanding, which in turn discourages and hampers the adoption, use and application of the seven approaches by inexperienced, untrained and amateur mHealth (promotion) behaviour change app intervention designers and developers.

Lastly, a critical cross-comparative analysis of Approaches #17, #18, #19 and #20 reveals none of them as recognising or discussing any concepts or constructs regarding community of practice theory, boundary object theory and knowledge boundary theory. This limitation has already been acknowledged and discussed in Subsections 6.4.1.7, 6.4.2.7 and 6.4.3.7, and as already noted, the failure of the four approaches to identify themes and subthemes relevant to the boundary object view further verifies the novelty of the proposed theoretical framework (lens). Yet, at the same time, yields less rich comparative and thematic analysis findings from the four integrative multi- and interdisciplinary approaches. On a final note, a range of other noteworthy limitations, gaps, weaknesses and lessons learned can be referred to in Table D under Appendix H; although, to reiterate, these points are neither copious nor comprehensively extensive.

# Appendix J.1 (Chapter 7): Actors Summary Overview

### 7.3.1.3 Proposed Framework "Actors" Component: Actors Summary Overview

Table 7.2 provides a brief summary overview of the actors discussed in Section 7.3, by outlining the heterogeneous communities of practice (and hence the different interdisciplinary team members) with direct participatory involvement in any given mHealth (physical activity) behaviour change intervention app project, as well as the third party stakeholders and end users with indirect participatory involvement. In Table 7.2, for each identified practice community, there is a brief description and a few actor examples. A more detailed summary overview of the actors discussed in Section 7.3, with elaborated descriptions, more examples and reference sources (from both literature and the critical analysis findings) is provided in Appendix J.1.

Important to note is that the descriptions in Table Appendix J.1 convey the practice community's dominant perspective orientation, and does not imply that the community actors are unfamiliar with the other communities' perspectives. For example, works by Michie, et al. (2011; 2013; 2016), Michie, van Stralen and West (2011) and Yardley (2015a; 2015b) are predominantly positioned in the overarching "health behavioural intervention community", yet many of their published works consider and incorporate perspectives from the "information systems community". The primary focus description merely assists in simplifying the distinctions between the heterogeneous communities of practice. Table Appendix J.1 also specifies the clustered sub-communities within each overarching practice community, provides examples of specific actor, and identifies the reference sources that informed the practice communities, sub-communities and actor examples. Reference sources include findings from both literature and the twenty approaches reviewed in the critical theoretical analysis (approaches are indicated with Approach numbers (#'s) (in accordance with the Approach # numeric notation established in Table 6.6 (Chapter 6, Subsection 6.3.2.3.4).

*Table Appendix J.1: Actors Summary Detailed Overview*
*[Source: Researcher's own construction]*

| Overarching Community of Practice | Overarching Community of Practice and Actor Description | Community of Practice Sub-Communities | Examples of Actors | Reference Sources: Approach Number (#) and Literature |
|---|---|---|---|---|
| **Interdisciplinary Team** | The interdisciplinary team of heterogeneous actors are localised in a diversity of practice communities that hold alternate worldview perspectives, yet work together collaboratively when engaging in boundary spanning, boundary crossing and knowledge sharing practices within a shared project (boundary) problem and solution space.<br><br>The interdisciplinary team members hold positioning, and political and decision-making power in driving/hindering the project, process, activities and product output.<br><br>Democratically, team members are referred to as digital health intervention designers and developers. | • Team Lead, Project Management and Primary Empirical Study Facilitation<br>• Health Behavioural Intervention Community<br>• Information Systems Community<br>• Health Behavioural Intervention Community<br>• Persuasive Technology and Game Development Community<br>• Business and Product Development Community<br>• Computer Science Community | • Interdisciplinary Team Leader<br>• Project Manager<br>• Community of Practice (localised) General Team Members<br>• Digital Health Intervention Team Designer<br>• Digital Health Intervention Team Developer | • Approach #1 to Approach #20<br>• Suchman (1994)<br>• Star and Griesemer (29189)<br>• Wenger (2000)<br>• Levina and Vaast (2005)<br>• Akkerman and Bakker (2011)<br>• Bakker and Akkerman (2014)<br>• Rosenkranz, Vranešić and Holten (2014)<br>• Worrall (2014)<br>• Kowatsch, et al. (2019)<br>• Sucala, et al. (2019) |
| **Team Lead and Project Management**<br><br>**Primary Empirical Study Facilitation** | The team leader(s), project manager(s) and primary empirical study facilitators serve as knowledge brokers within the shared project (boundary) problem and solution space. Knowledge brokers are weakly linked to all participating communities of practice, yet are full members of none.<br><br>The team lead and project management actors practice knowledge brokering when coordinating the heterogeneous team members, and when directing, guiding, managing and supporting the team throughout the project and interdisciplinary process.<br><br>The primary empirical study facilitators conduct, facilitate and supervise studies intended to gather information pertaining to the project or process steps or activities, and work closely with the team leader/project manager. | • Team Lead (Knowledge Boundary Brokering, primary chief role)<br>• Project Management (Knowledge Boundary Brokering, primary chief role)<br>• Primary Empirical Study Facilitation (Knowledge Boundary Brokering, secondary, facilitation and information gathering role) | • Interdisciplinary Team Leader (Team Knowledge Boundary Broker) (e.g. HI-U Specialist, #16)<br>• Prototyping Workshop Facilitator<br>• Expert Review Facilitator<br>• Usability Testing Evaluator<br>• Beta Testing Evaluator<br>• RCT MOST, SMART and TIPs Evaluators | • Approach #1<br>• Approach #2<br>• Approach #12<br>• Approach #14<br>• Approach #15<br>• Approach #16<br>• Wenger (1998)<br>• Levina and Vaast (2005)<br>• Meyer (2010)<br>• Blackman, Kennedy and Ritchie (2011)<br>• Letts, et al. (2014)<br>• Rosenkranz, Vranešić and Holten (2014)<br>• Haas (2015)<br>• Olejniczak (2017) |

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| **Health Behavioural Intervention Community** | Team members localised within the broader health behavioural sciences intervention community primarily adopt a health and intervention design, development and evaluation perspective of the shared problem and solution boundary space.<br><br>Focus is primarily orientated towards theory and evidence-based methods, strategies, techniques, content, sequence, themes and scope of health behaviour change interventions. | • Health Promotion Community<br>• Health Psychology Community<br>• Health Behavioural Change Intervention Sciences Community<br>• Health Behaviour Specialist Domain Practice Community (e.g. Sport Sciences, Exercise Sciences) | • Health Psychologist<br>• Health Behaviour Change Intervention Designer<br>• Physical Activity Expert<br>• Exercise Scientist<br>• Personal Trainer | • Approach #1 to Approach #9<br>• Approach #13<br>• Approach #14<br>• Michie, et al. (2011; 2013)<br>• Michie, van Stralen and West (2011)<br>• Davis, et al. (2015)<br>• Michie, et al. (2015; 2016; 2018)<br>• O'Cathain, et al. (2019)<br>• Kowatsch, et al. (2019)<br>• Sucala, et al. (2019) |
| **Information Systems Community** | Team members localised within the broader information systems community primarily adopt a digital technology (systems, mobile and app) and software design, development and evaluation perspective of the shared problem and solution boundary space.<br><br>Focus is primarily orientated towards the theoretical, conceptual and instantiated iterative design, development and evaluation of the digital technology (app) user flows, software features, functionalities and interactive components, through which the health behaviour change intervention is delivered. | • Information Systems Community<br>• Mobile and Smartphone App Design and Development Community<br>• Human-Computer Interaction Community<br>• User-Centred and User Experience Design Community(ies)<br>• Systems and Software Engineering Community<br>• Cognitive and Usability Engineering Community | • Information Systems Analyst<br>• Information Systems Designer<br>• Smartphone App Designer<br>• Human-Computer Interaction Designer<br>• User Experience Design Expert<br>• Mobile and App Software Engineer | • Approach #1<br>• Approach #2<br>• Approach #5 to Approach #13<br>• Approach #15 to Approach #20<br>• Stoyanov, et al. (2015; 2016)<br>• Miah, Gammock and Hasan (2017)<br>• Patel and Arya (2017)<br>• Sucala, et al. (2019)<br>• Kowatsch, et al. (2019)<br>• Kirkscey (2020) |
| **Business and Product Development Community** | Team members localised within the broader business and product development community primarily adopt a business and commercial perspective of the shared problem and solution boundary space.<br><br>Focus is primarily orientated towards consumers and the product's design, development and evaluation. Focus is also primarily orientated towards project, business and financial models and analyses, marketing and commercial (consumer) product releases. | • Business Development Community<br>• Product Design and Development Community<br>• Finance Management and Monetisation<br>• Consumer and Mobile App Marketing | • Business Analyst<br>• Consumer Market Analyst<br>• Product Designer<br>• Product Developer<br>• Consumer App Marketing Specialist<br>• Consumer App Monetisation Model Manager | • Approach #1<br>• Approach #2<br>• Approach #11<br>• Approach #12<br>• Approach #15<br>• Approach #16<br>• Approach #18 to Approach #20<br>• Petersen, Adams and DeMuro (2015)<br>• Nieborg (2016)<br>• Francis (2017)<br>• Kao and Liebovitz (2017)<br>• Sucala, et al. (2019) |

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| **Computer Sciences Community** | Team members localised within the broader computer sciences community primarily adopt a technical build and programming perspective of the mobile app within the shared problem and solution boundary space.<br><br>Focus is orientated towards data structures and algorithms, (mobile app) databases, hardware, infrastructure, architecture, networking, programming, and privacy and security. | • Computer Sciences Community<br>• Mobile Architecture and Infrastructure Community(ies)<br>• Mobile Software Development and Mobile App Server Community(ies)<br>• Data Analytics and DevOps<br>• Open-Source Software Consultants | • App Developer<br>• Mobile Software Developer<br>• Information Architect<br>• Open-Source Software Consultant<br>• Data analyst<br>• DevOps Engineers<br>• Privacy Expert<br>• Security Expert | • Approach #7 to Approach #9<br>• Approach #11<br>• Approach #12<br>• Approach #15<br>• Approach #16<br>• Approach #18 to Approach #20<br>• Oluwafemi and Olanrewaju (2014)<br>• Vagg, Plant and Tabirca (2016)<br>• Francis (2017)<br>• Torre-Diez, et al. (2017)<br>• Taylor (2018)<br>• Mala (2019)<br>• Kowatsch, et al. (2019)<br>• Sucala, et al. (2019) |
| **Persuasive Technology and Game Development Community** | Team members localised within the broader persuasive technology and game development community primarily adopt persuasive behavioural change and gamification perspectives of the shared problem and solution boundary space.<br><br>Focus is orientated towards designing, developing and evaluating digital technologies by embedding persuasive and gamification theories, frameworks, models, strategies, techniques and design software feature principles and elements intended to target behavioural changes in individuals. | • Persuasive Technology and Persuasive Systems Design Community(ies)<br>• Health Behavioural Change Support Systems Community (including mHealth)<br>• Game Design and Development Community | • Persuasive Systems Software Designer<br>• mHealth Behavioural Change Support System Designer<br>• Game Designer<br>• Game Developer<br>• Game Analyst | • Approach #2<br>• Approach #7<br>• Approach #10<br>• Approach #17<br>• Approach #19<br>• Oinas-Kukkonen and Harjumaa (2009)<br>• Langrial, et al. (2012; 2017)<br>• Payne, Moxley and MacDonald (2015)<br>• Hu, Hsieh and Feng (2018)<br>• Cotton and Patel (2019) |
| **Third Party Stakeholders** | The interdisciplinary team may call upon, contract, partner or consult with a variety of third party stakeholders at various steps or activities of the project process.<br><br>Third-party stakeholders are localised outside of the interdisciplinary team, and offer indirect involvements and contributions for specific purposes. | • Project Funders and Investors<br>• Health Behaviour Specialist Consultants<br>• Healthcare Organisations<br>• Mobile, Wireless and Software App Companies<br>• Data Analytics and DevOps Companies and Consultants<br>• Open-Source Software Providers<br>• Academic Institutions and Research Groups<br>• Policy Makers, Legislative and Regulatory Officials | • Physical Activity Expert Consultant<br>• Health Behaviour Change Intervention App Researcher<br>• Mobile App Developer Consultant<br>• Data Analytics Consultant<br>• DevOps Engineer Consultant | • Approach #1 to Approach #4<br>• Approach #6 to Approach #10<br>• Approach #12 to Approach #18<br>• Petersen, Adams and DeMuro (2015)<br>• Francis (2017)<br>• Kao and Liebovitz (2017)<br>• Patel and Arya (2017)<br>• Taylor (2018)<br>• Mala (2019)<br>• Kowatsch, et al. (2019) |

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| **End Users**<br><br>**(Target Population Group Representatives)** | Sample representatives of the defined target population group may collaborate and/or engage with the interdisciplinary team during various steps or activities of the project process.<br><br>End users may directly or indirectly participate in and contribute to a variety of design, development and evaluation activities.<br><br>Direct end users form part of the interdisciplinary team, constituting participatory approaches. Indirect end users do not partake as members of the interdisciplinary team, and remain bounded outside of the team boundary. | • Direct End User Participation Involvement<br>• Indirect End User Participation Involvement | • A sample of end user participants serving as representatives of a defined target population group<br>• End user group for prototype design and development<br>• End user group for usability testing<br>• End user group for pilot testing | • Approach #1 to Approach #20<br>• Craven, Lang and Martin (2014)<br>• Petersen, Adams and DeMuro (2015)<br>• Yardley (2015a; 2015b)<br>• Patel and Arya (2017)<br>• Moore, et al. (2019)<br>• Kowatsch, et al. (2019) |

# Appendix J.2 (Chapter 7): Interdisciplinary Collaborative Team Member and Perspectives Template

### 7.3.2.1 Actors: Application: A Proposed Interdisciplinary Collaborative Team Member and Perspectives Template

The identification, selection and formation of interdisciplinary collaborating team members is an integral initiative part of the project and team formalisation process (Step 1 in the *"interdisciplinary collaborative process"*, Table 7.1). An inherent quality of interdisciplinary collaborative teamwork is that heterogeneous actors, stemming from diverse communities of practice, are generally unfamiliar with other communities' perspectives, approaches/methods, theories and practices (Star and Griesemer, 1989; Suchman, 1994). It is in the shared problem and solution space that heterogeneous intersecting practice community members possess a lack of other team members' specialised knowledge, expertise, skills and experience (Suchman, 1994). To avoid team members developing false assumptions and misinformed conceptions, and discounting and invalidating each other's relevant and meaningful contributions to the design, development and evaluation of mHealth intervention apps, is it important that team members have a general awareness of other members' communities of practice, perspectives and contributions (Worrall, 2014).

Therefore, after an interdisciplinary collaborative team has been established, it is necessary that an understanding of each team member's respective community of practice, perspectives and contributions be explicitly articulated and communicated, thereby bridging the (often mistaken) perceptual and conceptual boundary divides between collaborating actors (Filip, 2016). A willingness to engage in perspective-taking, which entails acknowledging and being mutually respectful towards practice communities outside of one's own, is imperative for productive interdisciplinary team collaboration (Haas, 2015; Filip, 2016). To help foster theory of mind, cooperation, empathy and collaboration, and to counter intra-team disrespect, mistrust and conflict, it is recommended that all of the interdisciplinary team members share their diverse perspectives, knowledge, skills, expertise, interpretations, roles, interests, aims/goals and contributions (Nancarrow, et al., 2013).

Developing a shared *Interdisciplinary Collaborative Team Member and Perspectives Template*, in relation to the mHealth intervention app project and product context, can promote dialogic perspective-making, perspective-taking and sensemaking engagements between team members (Worrall, 2014; Mayo and Woolley, 2016). This interdisciplinary team perspectives template activity starts to build a solid basis for shared understanding amongst diverse team members, which becomes the foundation for team communication, cooperation, coordination, collaboration and negotiation practices (relevant to *"Main Component 4: Knowledge"*), and importantly, assists the team when designing, developing and evaluating a joint mHealth intervention app solution (Boujut and Blanco, 2003; Gomes and Tzortzopoulos, 2018).

Table Appendix J.2 provides a simple example for how interdisciplinary collaborating teams can frame their own mHealth intervention app project's *Interdisciplinary Collaborative Team Member and Perspectives Template*. When creating the template, it is necessary that all members of the interdisciplinary collaborating team contribute to gain a holistic perspective understanding of the diversity within the project team. A template can be drawn for each team member, and can be referred to by other team members at any stage of the project lifespan. The example provided in Table Appendix J.2 is given in the context of one team member serving as a user experience design (UXD) expert in a mHealth physical activity behaviour change intervention app project, in accordance with the framework's proposed interdisciplinary collaborative process (Figure 7.2; Table 7.1).

*Table Appendix J.2: Interdisciplinary Collaborative Team Member and Perspective Template: Example of a User Experience Design (UXD) Expert in a mHealth Physical Activity Behaviour Change Intervention App Project [Source: Researcher's own construction, informed by critical theoretical analysis findings (Chapter 6); Boujut and Blanco (2003); Worrall (2014); Nancarrow, et al. (2013); Bartholomew Eldredge, et al. (2016); Filip (2016); and Gomes and Tzortzopoulos (2018)]*

| **Interdisciplinary Collaborative Team Member and Perspectives Template** | | |
|---|---|---|
| **Team Member Perspective** | **Perspective Components** | **Example** |
| **Team Member Specialist Knowledge and Expertise** | • Overarching community of practice | • Information Systems Community |
| | • Knowledge domain, field and/or discipline | • User Experience Design (UXD) |
| | • General area of specialist knowledge and expertise | • Mobile User Experience Design (mUXD) |
| | • Specific area of specialist knowledge, skills, expertise and experience in relation to the mHealth physical activity behaviour change intervention app project | • mHealth UXD expert with ten years' experience, and eight years' experience with physical activity consumer apps. |
| **Key Perspectives** | • Paradigmatic worldview perspective | • Pragmatic, sociomaterial |
| | • Theoretical frameworks, models and approaches prevalent and commonly employed in practice | • BASIC framework, Heart framework, mUXD principles, Design Thinking process, UXD process. |
| | • General perspective of the (shared) problem space | • There is a disregard for end users' /consumers' experiences, which deters their acceptance, adoption and sustained usage of an app and intervention content over time. |
| | • General perspective of the (shared) solution space | • Creating for positive and enhanced end users/consumers experiences with the mHealth app can improve their adoption, acceptance, engagement and sustained usage of the app, and enhance the intervention's effectiveness. |
| | • (Subjective) perspective of own role and positioning as team member in relation to all other team members (Scale: high, moderate, low, negligible) | • High role and positioning power (influence) during Steps 4, 5 and 6 of the process.<br>• Moderate role and positioning power (influence) during Steps 8 and 9.<br>• Moderate role and positioning power (influence) during Step 1 and 2.<br>• Low role and positioning power (influence) during Step 7. |
| | • Key interests and values in terms of the project, process and product context | • To create for positive and enhanced user experiences with the mHealth physical activity intervention app. |

| | | |
|---|---|---|
| | • Aims, goals and objectives in terms of the project, process and product context | • Design and produce a mHealth intervention app that is engaging, enjoyable and positively changes individuals' physical activity. |
| **Contribution** | • Specific knowledge, skills and expertise contribution to the mHealth behaviour change intervention app project | • mUXD perspective and experienced specialist knowledge input. |
| | • Specific contribution to interdisciplinary collaborative process, steps and activities | • Activities pertaining to the design, development and evaluation of mUXD principles and end users'/ consumers' experiences. |
| | • Specific contribution towards an improved understanding of the (shared) problem space | • Understanding the target population end users' preferences for positive experiences and design features/principles |
| | • Specific contribution towards an improved understanding of the (shared) solution space | • An enriched understanding of how designing for positive user experiences enhances the mHealth app's engagement, sustained usage, and intervention effectiveness |
| | • Specific contribution to final product output | • A mHealth physical activity app that incorporates mUXD principles as software design features and fosters positive user experiences. |
| **Willingness and Commitment** | • To respect and trust other team members' diverse perspectives, specialist knowledge, skills, expertise, activities, practices and contributions | • Moderate willingness and commitment |
| | • To engage in communication, coordination, cooperation, collaboration and cohesion practices | • High willingness and commitment |
| | • To engage in perspective-making and perspective-making dialogic interactions and practices | • High willingness and commitment |
| | • To engage in mentalisation (theory of mind) | • Moderate willingness & commitment |
| | • To empathise with alternate perspectives outside own | • Moderate willingness & commitment |
| | • To team's shared interdisciplinary collaborative process steps and activities | • High willingness and commitment |
| | • To employ, use, adapt, create and manage appropriate boundary objects and supporting artefacts | • Moderate willingness and commitment |
| | • To develop common ground and shared understanding | • Moderate-to-high willingness and commitment |
| | • To negotiations and compromises in the face of differences and conflicts | • Moderate willingness and commitment |
| | • To knowledge sharing, integration, transformation and generation (creation) | • Moderate and commitment |
| | • To trade-off specialist knowledge, skills, expertise and practices in order to jointly transform the project, process and product output collaboratively | • Low willingness and commitment |

# Appendix J.3 (Chapter 7): Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams

### 7.3.2.1 Actors: Application: Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams

Collaboration is indispensable for interdisciplinary teamwork in mHealth (physical activity) behaviour change intervention projects (van Gemert-Pijnen, et al., 2011; Lathia, et al, 2013; Nancarrow, et al., 2013; Mohr, et al., 2014; Knittle, et al., 2016; Murray, et al., 2016; Mummah, et al., 2016; Michie, et al., 2017; Lai, et al., 2017; van Gemert-Pijnen, et al., 2018; Mahmood, et al., 2019). Good interdisciplinary team collaboration is built upon solid foundations of communication, coordination, cooperation and cohesion (Nancarrow, et al., 2013; Lopez, et al., 2018). *Communication* can be described as a process by which information is transferred or exchanged between two or more interdisciplinary team members through a common system of dialogue, signs, symbols or behaviours (Fong, Srinivasan and Valerdi, 2007). Communication is important for sensemaking and sharing interpretations of meaning, and in an interdisciplinary team setting, supports boundary spanning and boundary crossing engagements (Fong, Srinivasan and Valerdi, 2007; Lopez, et al., 2018).

*Coordination* goes beyond communication by taking information and applying it for a purpose, and usually requires that certain specified conditions be abided by (Nancarrow, et al., 2013; Klein, 2014). Coordination aims to bring together activities into a common (aligned or synchronised) actionable activity in order to achieve a defined (shared) goal or activity objective (Carlile, et al., 2013). Coordination involves the altering of tasks, (localised and joint) activities, interactions, information flows and the shared use of common materials and infrastructures in order to benefit the team and attain a common goal (Fong, Srinivasan and Valerdi, 2007). Coordination is essential for organising, aligning and structuring the various practice communities' heteropraxial design, development and evaluation activities. *Cooperation* builds on coordination in aiming to improve something (such as an app's design) by engaging in processual compliance as a means to achieve a shared pursuit or goal (Klein, 2014). Cooperative efforts are important for interdisciplinary project contexts, and involve

sharing information, changing activities and sharing common materials, resources and infrastructures (Iivari, 2019).

*Collaboration* surpasses cooperation with the aim to engage interdisciplinary team members in joint problem-solving activities and processes in order to create something new or to collectively improve something (Dupont, et al., 2012; Nancarrow, et al., 2013). Collaboration is a complex phenomenon that requires mutual learning, cooperative engagements and co-performed practices for innovative and creative ideas and solutions to be achieved (Sander, Nolwenn and Céline, 2019). Co-definition, co-design, co-development, co-production, co-implementation and co-evaluation activities (as incorporated in the proposed framework's interdisciplinary collaborative process activities) are characteristic of successful collaborative engagements (Nancarrow, et al., 2013; Melville-Richards, 2015; Kowatsch, et al., 2019; Sander, Nolwenn and Céline, 2019). *Cohesion* builds on good communication, coordination, cooperation and collaboration practices. Cohesion describes the camaraderie established in interdisciplinary collaborating teams that have worked together over time due to familiarity among members, and promotes insight, hunches, experimentation, calculated risk-taking and innovation in teams, which is important for designing better, more effective mHealth (physical activity) behaviour change intervention consumer app product solutions (Lakhani, Benzies and Hayden, 2012).

High-performing interdisciplinary collaborative teams are able to leverage the diverse perspectives contributed by each participating community of practice, and engage effectively in communication, coordination, cooperation, collaboration and cohesion activities, practices and processes over the duration of a given mHealth intervention app project (Oehlberg, 2012). Notably, high-performing interdisciplinary collaborating teams are not immune from negotiation and conflict resolution practices, but are able to resolve differences in language, perspectives, interpretations of meaning, interests and goals, and establish shared understandings and common grounds in order to achieve a shared ultimate aim (that is, to produce an effective mHealth physical activity behaviour change intervention app product).

Table Appendix J.3 provides guideline recommendations for high-performing interdisciplinary collaborative teams to be aware of and consider when partaking in mHealth (physical activity) behaviour change intervention app projects. The guideline recommendations provided are not extensive or exhaustive. Instead, Table Appendix J.3 intends to offer interdisciplinary collaborating teams of mHealth intervention app projects a basic frame from which they can

build upon and adapt to foster high-performance team collaboration. Similar to the proposed *Interdisciplinary Collaborative Team Member and Perspectives Template* activity, the *Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams* helps strengthen the foundation for communication, coordination, cooperation, negotiation, cohesion and shared understanding practices between collaborating heterogeneous community of practice actors.

*Table Appendix J.3: Guideline Recommendations for High-Performing Interdisciplinary Collaborating Teams [Source: Researcher's own construction, informed by Carlile (2002; 2004; 2006); NHS (2010); Dupont, et al. (2012); Likhani, Benzies and Hayden (2012); Oehlberg (2012); Nancarrow, et al. (2013); Ben-Zeev, et al. (2015); Melville-Richards (2015); Filip (2016); Koskela (2016); Pikas, et al. (2016); CordisBright (2018); Pikas, et al. (2018); Sander, Nolwenn and Celine (2019)]*

| **Guideline Recommendations for High-Performing Interdisciplinary Collaborating Teams** | | |
|---|---|---|
| **Guideline Recommendation** | **Description and Key Pointers** | **Reference** |
| **Interdisciplinary Collaborative Team Membership and Diversity** | • All heterogeneous team members possess relevant and required knowledge, expertise, skills and experience applicable to the mHealth (physical activity) behaviour change intervention app project<br>• Interdisciplinary collaborative team contract<br>• Clear team purpose<br>• Value diverse community, skill, personality and attribute mixes<br>• Consider and clearly understand different perspectives and contributions of each team member *(Interdisciplinary Collaborative Team Member and Perspectives Template)*<br>• Contribution limitations of each team member are understood | • NHS (2010)<br>• Likhani, Benzies and Hayden (2012)<br>• Nancarrow, et al. (2013)<br>• O'Reilly, et al. (2017) |
| **Interdisciplinary Collaborative Team Leadership** | • Leader with good leadership characteristics<br>• Good team leadership (transformational leadership)<br>• Good team management | • Likhani, Benzies and Hayden (2012)<br>• Nancarrow, et al. (2013) |
| **Interdisciplinary Collaborative Team Communication** | • Frequent and good two-way communication that allows all team members to speak and listen within team context<br>• Clear and open communication to discuss and resolve difficulties<br>• Explicit articulation of knowledge, opinions and suggestions | • Nancarrow, et al. (2013)<br>• O'Reilly, et al. (2017) |
| **Interdisciplinary Collaborative Team Culture** | • Mutual trust<br>o Contractual trust: the expectation that team members will adhere to contractual agreements, strategies and plans<br>o Competence trust: the expectation that team members will perform their role(s) and activities responsibly and competently | • NHS (2010)<br>• Likhani, Benzies and Hayden (2012) |

| | | |
|---|---|---|
| | • Goodwill trust: a mutual expectation of open commitment between team members (and/or third-party stakeholders)<br>• Mutual respect<br>  o Mutual respect for all team members<br>  o Mutual respect for all team member roles and positions<br>  o Mutual respect for diverse perspectives and voices<br>• Equal voice for all team members<br>• Encourage tacit knowledge sharing<br>• Encourage constructive negotiation and conflict resolution practices<br>• Foster shared problem solving<br>• Foster mutual learning<br>• Foster innovative idea and knowledge generation<br>• Foster flexibility to adapt to changes and challenges<br>• Encourage give-and-take relations through reciprocity, compromise and mutual exchange<br>• Foster good team camaraderie and support/relationships<br>• Foster fun and enjoyable environment<br>• Foster team cohesion<br>• Appropriate team member recognition and rewards | • Nancarrow, et al. (2013)<br>• Melville-Richards (2015)<br>• Filip (2016)<br>• O'Reilly, et al. (2017)<br>• CordisBright (2018) |
| **Individual Team Member Attributes** | • Valuable personal attributes of individual team members:<br>  o Good communication and interpersonal skills<br>  o Active listening skills<br>  o Empathy<br>  o Approachability<br>  o Good organisational skills<br>  o Confidentiality<br>  o Decisiveness<br>  o Ability and willingness to take initiatives<br>  o Innovative<br>  o Ability and willingness to compromises<br>  o Aware of one's own strengths and weaknesses<br>  o Openness to learning and growing<br>  o Self-reflection and reflexivity<br>  o Patience and tolerance | • Likhani, Benzies and Hayden (2012)<br>• Nancarrow, et al. (2013) |
| **Interdisciplinary Collaborative Team Willingness and Commitment** | • Team members should be willing and committed to invest time and effort towards:<br>  o The interdisciplinary collaborative process<br>  o The mHealth behaviour change intervention app product<br>  o Perspective-making and perspective-taking dialogic interactions and practices<br>  o Mentalisation (theory of mind) practices<br>  o Developing common ground and shared understandings<br>  o Engaging in shared decision-making<br>  o Negotiating differences and arriving at mutual compromises<br>  o Resolving conflicts through discussions and negotiations<br>  o Giving and receiving constructive criticism and feedback | • Filip (2016)<br>• Pikas, et al. (2016)<br>• Koskela, et al. (2016)<br>• Pikas, et al. (2018) |

| | | |
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| | • Willingness to trade-off specialist knowledge and practices to jointly transform the project, process and product output collaboratively | |
| **Interdisciplinary Collaborative Team Training and Development** | • Opportunities for team members to learn, grow and continuously develop knowledge, skills and competencies through ongoing:<br>o Professional development<br>o Education<br>o Training and development programmes/workshops<br>o Knowledge sharing<br>o Knowledge integration and generation | • Nancarrow, et al. (2013) |
| **Conceptual Interdisciplinary Collaborative Teamwork** | • Commitment to the development of shared understandings by:<br>o Sharing knowledge across community boundaries<br>o Developing shared project goals and objectives<br>o Developing shared interdisciplinary collaborative process goals<br>o Developing shared product goals and objectives<br>o Developing a shared vision<br>o Co-creating common ground(s)<br>o Co-creating common language(s)<br>o Co-creating common meaning(s)<br>o Co-creating shared mental models (common frames of reference)<br>o Co-creating common interests<br>o Establishing cognitive and perspective conflict resolution plans<br>o Co-developing "mHealth stories" (Ben-Zeev, et al., 2015, p.161) | • Carlile (2002; 2004; 2006)<br>• Oehlberg (2012)<br>• Ben-Zeev, et al. (2015)<br>• Filip (2016)<br>• Pikas, et al. (2016)<br>• O'Reilly, et al. (2017)<br>• Pikas, et al. (2018) |
| **Practical Interdisciplinary Collaborative Teamwork** | • Commitment to collaboratively partake and actively perform in:<br>o Knowledge sharing and knowledge integration activities/processes<br>o Shared understanding activities/processes<br>o Shared decision-making activities/processes<br>o Shared negotiation and conflict resolution activities/processes<br>o Knowledge transformation activities/processes<br>o Innovative idea generation activities/processes<br>o Interdisciplinary collaborative design, development and evaluation process steps and activities that lead to the production of a mHealth behaviour change intervention app product | • Carlile (2002; 2004; 2006)<br>• Dupont, et al. (2012)<br>• Ben-Zeev, et al. (2015)<br>• Filip (2016)<br>• Sander, Nolwenn and Céline (2019) |
| **Material Interdisciplinary Collaborative Teamwork** | • Availability of and access to sufficient physical materials/resources:<br>o Physical or virtual office space<br>o Computers, digital devices and stable internet connectivity<br>o Manual materials (e.g. paper, pens, notebooks, etc)<br>o Equipment, tools and software | • Nancarrow, et al. (2013) |

# Appendix K.1 (Chapter 7): Elaborated Justifications for Employing the Term "Interdisciplinary"

### 7.4.2.1 Characteristics of the Interdisciplinary Collaborative Process: Employing the Term "Interdisciplinary"

The term *"interdisciplinary"* is employed, rather than alternative "crossdisciplinary", "multidisciplinary" or "transdisciplinary" phrasing, for a few reasons. Firstly, in terms of terminological descriptions, interdisciplinary teamwork aims to integrate, blend and synthesise diverse disciplines' concepts, theories, approaches, methods and tools in order to address shared complex problems and achieved shared goals through holistic views (Klein and Roessner, 2014). In contrast to this, crossdisciplinary work aims to view one discipline or community of practice from the perspective of another, and boundaries remain distinctly separate (Klein and Roessner, 2014). Multidisciplinary teamwork aims to juxtapose and coordinate two or more disciplines together in order to address a specific problem; however, the disciplines and their respective views remain distinctly separate and not integrate or blend (Klein and Roessner, 2014). Transdisciplinary teamwork aims to transform, transgress and transcend current knowledge, processes and practices by largely dissolving disciplinary boundaries and creating new supradisciplinary paradigms through an overarching synthesis (Klein and Roessner, 2014). Interdisciplinary teamwork lies on a continuum between multidisciplinary and transdisciplinary, and allows for the undertaking of critical and pragmatic research without needing to tend to or define new epistemological and institutional structures (Klein and Roessner, 2014; Uusitalo, 2015). These different terminological descriptions indicate "interdisciplinary" as the most appropriate term of use in this research study context.

Secondly, in interdisciplinary teamwork, the disciplinary (community of practice) boundaries overlap (as illustrated in Figures 5.4, 5.5, 5.6, 5.7, Chapter 5), creating the need for active collaboration where social integration, project management and communication, negotiation and political power dynamics are introduced into shared processes and heteropraxial activities (Klein and Roessner, 2014). In comparison, in multidisciplinary teamwork, the disciplinary boundaries remain separate and do not overlap, in which case team members continue to work within their own disciplinary silos and emphasise is given to cooperation and coordination

rather than ongoing, active collaboration (Klein and Roessner, 2014). In transdisciplinary teamwork, the disciplinary boundaries are largely dissolved and the distinctions between formerly overlapping boundaries are challenging to clearly decipher and separate (Klein and Roessner, 2014). Figure Appendix K.1 provides a simple graphical representation of boundaries in multidisciplinary, interdisciplinary and transdisciplinary teamwork, respectively. In light of the relative, although not fully-fledged, boundary overlaps in interdisciplinary teamwork, the term "interdisciplinary" is deemed most suitable for use in this research study.

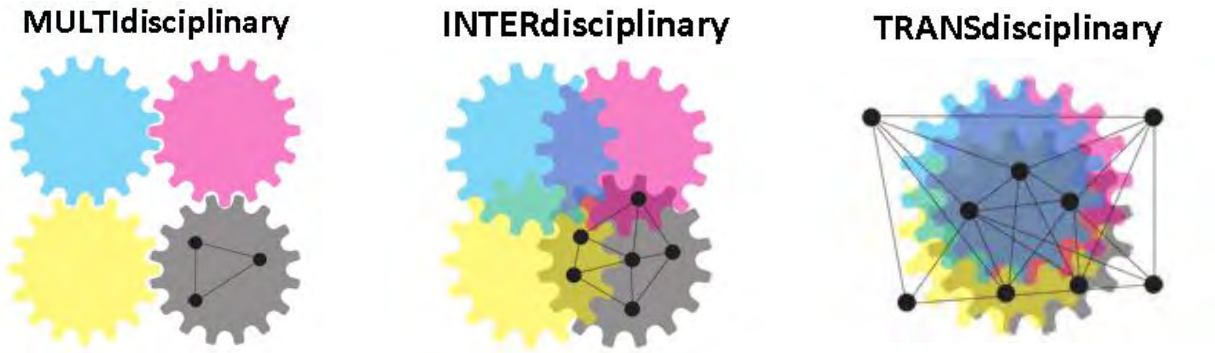



*Figure Appendix K.1: Boundaries in Multidisciplinary, Interdisciplinary and Transdisciplinary Teamwork [Source: Adapted from Priest (2021)]*

Thirdly, although initially described during its inceptive years as multidisciplinary, literature in recent years increasingly refers to the digital health and mHealth behaviour change intervention app arenas as interdisciplinary fields of study (Blandford, et al., 2018; Arigo, et al., 2019; Blandford, 2019a; 2019b; Sucala, et al., 2019; Sellak and Grobler, 2020; Przybylko, et al., 2021), particularly in terms of physical activity apps (McCallum, 2019; Torous, et al., 2019). This evident literary progression towards using the term "interdisciplinary" as a descriptive for the mHealth behaviour change intervention app arena evidences its appropriate use in this research study.

Fourthly, while the critical analysis findings demonstrate oscillating shifts between various descriptions of multidisciplinary and interdisciplinary knowledge, theories, processes and praxes in mHealth intervention app research and real world practice, a general trend towards nurturing and growing an interdisciplinary knowledge base is evident. To elaborate, given the "young" (Mummah, et al., 2016, p.1) and "emerging" (Arigo, et al., 2019, p.72) nature of the mHealth behaviour change intervention app arena, the space is not yet clearly defined, scoped

or understood, and a multitude of known and unknown knowledge gaps still need to be addressed and resolved going forward (Arigo, et al., 2019). Given the complexities and intricacies of this newly evolving arena, the oscillating different descriptions and arguments for multidisciplinary as well as interdisciplinary teamwork becomes discernible. These shifts are recognised by Choi and Park (2006) and Iivari (2019, p.13), who discuss the "constant oscillation between multi- and interdisciplinary" processes and practices in complex and wicked information systems design research. It is therefore apparent that while the growing mHealth behaviour change intervention app field exhibits ambiguous shifts and vacillations between multidisciplinary and interdisciplinary descriptions, there is a general increasing trend towards the use of the term interdisciplinary as appropriate for this particular arena, and a growing desire and call for the advancement of theory and generation of new knowledge that is interdisciplinary in nature (Blandford, et al., 2018; Arigo, et al., 2019; Blandford, 2019a; 2019b; Sucala, et al., 2019; Sellak and Grobler, 2020; Przybylko, et al., 2021).

# Appendix K.2 (Chapter 7): The Nature of the Interdisciplinary Collaborative Process

### 7.4.2.3 The Nature of the Interdisciplinary Collaborative Process

The *nature* of the interdisciplinary collaborative process was briefly introduced in Subsection 7.2.1.2, in reference to Figure 7.2, and is elaborated on in this subsection in relation to Figure 7.6. The interdisciplinary collaborative process nature can be disserved in terms of its (1) *structure*, (2) *iterative flexibility*, and (3) *quality*.

Firstly, in terms of *structure*, the interdisciplinary collaborative process assumes a *somewhat systematic* and *non-linear* nature. *Systematic* describes a process as having methodical, organised and logical qualities. Important to note is that a systematic nature does not necessarily denote a rigid, strict or inflexible prescriptive approach; therefore aligning with the argument and justifications discussed in Section 7.4.1. Systematic does however suggest a sufficiently logical approach. For example, in Figure 7.6, Step 3 cannot be carried out until Step 2 is adequately performed. This means that in order for the interdisciplinary collaborating team to develop a theoretical and conceptual base solution (Step 3) they need to have an adequate understanding of the problem space (Step 2). Another example (in relation to Figure 7.6) is that the interdisciplinary collaborating team needs to develop an instantiated conceptual and technological solution design (Step 4) before they can move forward to design and develop a concrete solution (Step 5). These examples convey the methodical, organised and logical nature of interdisciplinary collaborative process.

The systematic structure of the process should, however, not to the detriment or hindrance of flexibility and adaptability (Chen, 2019). For example, in the context of a mHealth (physical activity) behaviour change intervention app project, the interdisciplinary team may wish to conduct iterative cycles (feedback loops) between Step 4 and Step 5. This would indicate iterative designs, developments and refinements of the instantiated mHealth intervention app's solution, and an alignment between its conceptual and technological solution (Step 4) and its concrete and material solution (Step 5). This flexibility leans towards the interdisciplinary process's *non-linear* structure.

The interdisciplinary collaborative process adopts a *non-linear* structure. *Linearity* refers to the order and sequencing followed in carrying out process steps. Linear approaches can create setbacks in complex and wicked design problem and solution spaces considering that they are generally better suited to well-framed problems and assume reductionist and non-innovative practices (Chen, 2019). *Non-linearity* indicates that interdisciplinary collaborating team members need not necessarily follow the prescribed steps in a strict instructionally prescriptive and ordered manner, yet the underlying systematic structure of the process remains intact (Chen, 2019). Non-linearity is well suited to complex and collaborative design projects, particularly in cases involving multiple diverse perspectives and interests, and numerous iterative prototyping cycles (Chen, 2019). Non-linearity (albeit with sufficient systematic structure) corresponds to the non-rigid, non-strict, flexible, malleable and adaptive nature of the proposed process (described in Section 7.4.1). The pragmatic application of the process in practice depends on the "actual way" the interdisciplinary team plans and executes the process, and depends on the team members' knowledge, expertise, skills and experience, as well as the contextual factors and situational circumstances of the mHealth intervention app project and product objective (Bertelsen, 1998, p.57).

Secondly, the *iterative flexibility* of the interdisciplinary collaborative process is demonstrated by the nine crescent-like arrows between steps 2 and 9 (Figure 7.6), which caters for an *agile*, *cyclical feedback looping*, *continuous*, *adaptive*, *reflective* and *reflexive* process nature. While agile methodologies primarily originate from the information systems and software engineering disciplines, they are particularly well suited to the mHealth behaviour change intervention app environment, and have been increasingly adopted and applied in recent years (Jacobs and Graham, 2016; Edwards, et al., 2018; Thabrew, et al., 2018; Wilson, et al., 2018; Mala, 2019; Sucala, et al., 2019; Hermsen, et al., 2020). Agile, cyclical feedback looping, continuous, adaptive, reflective and reflexive process qualities also allow mHealth intervention apps to be continuously tracked, monitored, tested, updated and released over time, which is imperative for consumer app products to be successful in the digital mHealth environment (Francis, 2017; Tozzi, 2017; Taylor, 2018; Mala, 2019).

In sharp contrast to the strict rigid structure of traditional project methodologies (such as the waterfall approach), iterative and agile mHealth intervention app projects require continuous flexible interdisciplinary team collaboration, knowledge sharing and collective heteropraxial activity engagement (Tell, et al., 2017; Edwards, et al., 2018; Wilson, et al., 2018; Wohlrab,

Pelliccione and Larsson, 2018; Sucala, et al., 2019). Furthermore, the flexible iterative cyclical feedback loops allow project teams to cycle back to specific steps or activities of the process, or to reiterate the process as whole, when necessary and desired (Edwards, et al., 2018; Hermsen, et al., 2020). For example, the smaller cyclical (feedback loops) and reflective and reflexive circles of Steps 4, 5 and 6 in Figure 7.6 demonstrate faster mHealth intervention app prototyping iterations within the larger iterative and agile process of a given mHealth intervention project. These iterations are common practice in mHealth app prototype design-develop-test-refine activities performed during Steps 5 (alpha testing), 6 (beta testing) and 9 (continuous improvements, delta testing) (Edwards, et al., 2018; Peiris, Miranda and Mohr, 2018; Wilson, et al., 2018). Given the constant advancements in digital mobile app technology and evolving consumer expectations and demands, interdisciplinary teams need to continuously improve, update, maintain and deliver more innovative and effective mHealth behaviour change intervention consumer app products (Naeem, et al., 2015; Centercode, 2019).

Notably, one exception to the iteratively flexible and agile nine crescent-like arrows between steps 2 and 9 is the straight arrow from steps 1 to 2 (Figure 7.6), which conveys a more stable nature where a project's and team's formation and formalisation is generally established and clarified as a solid base foundation before the subsequent steps and activities are carried out. For example, in order to formulate a problem understanding (Step 2) and start developing a theoretical and conceptual base solution (Step 3), the interdisciplinary team would have first needed to be formed (with clearly defined roles and responsibilities) and the project scope would have needed to be clearly delineated and specified. Failure to establish a strong team and project formalisation in Step 1 will have negative consequences and ripple effects on the effectiveness and efficiency of subsequent steps and activities (Nancarrow, et al., 2013).

Thirdly, in terms of quality, the interdisciplinary collaborative process ought to be sufficiently *theory-based* and *evidence-based*. *Theory-based* essentially indicates that the process and its constituting steps (and activities) are informed and supported by, and established on, validated, credible and reliable theory(ies), theoretical frameworks and/or models. *Evidence-based* conveys that the steps (and activities) within the process have been previously empirically applied and tested in practice, and have demonstrated scientific proof (hence the word 'evidence') for validity, credibility and reliability. In addition, it is suggested that frameworks, models, tools, techniques, objects and artefacts employed and utilised by the team during the interdisciplinary collaborative process ought to be theory-based and evidence-based. Based on

the findings of the critical theoretical analysis, examples of theory- and evidence-based frameworks and models useful for employment during process Steps 2 and 3 include the BCW, COM-B, TDF, PSDM, and CALO-RE, BCTT v1 and DHI taxonomies.

Overall, the characteristics and nature qualities of the *"interdisciplinary collaborative process"* (main component 2) influence how an *"interdisciplinary team"* (main component 1) is able to pragmatically adapt and apply the process's steps and activities in real world practice. At the same time, the symbolic interactionist and sociomaterial enactment of the design, development and evaluation collaborative practices, and the subsequent product output (in the form of a mHealth (physical activity) behaviour change intervention consumer app), are largely influenced, moulded and impacted by the "actual" way an interdisciplinary collaborating team performs the steps and activities of an adapted shared process within a given mHealth intervention app project, problem and solution context (Bertelsen, 2000, p.23).

# Appendix K.3 (Chapter 7): The Interdisciplinary Collaborative Process Steps and Activities

## 7.4.3 The Interdisciplinary Collaborative Process Steps and Activities: A Detailed Overview

The proposed *"interdisciplinary collaborative process"* comprises nine steps; outlined in Table 7.1 and illustrated in Figures 7.2, 7.5 and 7.6. The proposed nine steps and their encompassing activities are informed by the critical theoretical analysis findings (Chapter 6 and Appendix J), the landscape and context literature chapters (Chapters 3 and 4), and additional literature that references specific activities and more recent approaches (published subsequently to the critical analysis sample selection process, such as Sucala, et al., 2019). Table 7.3 describes each of the nine process steps and activities. The nine process steps are: (1) *project and team formalisation*; (2) *problem understanding*; (3) *theoretical and conceptual base solution development*, comprising sub-steps (3.1) *theoretical base* and (3.2) *conceptual base*; (4) *instantiated conceptual and technological solution design*; (5) *instantiated concrete solution design and development*; (6) *formative evaluation*, comprising sub-steps (6.1) *pilot testing* and (6.2) *beta testing*; (7) *deployment*; (8) *summative evaluation*; and (9) *post-market release surveillance and continuous improvement*. For purposes of length, Table 7.3 has been condensed. Appendix K.3 provides a more comprehensive and detailed table describing the activities, along with some examples relevant to the mHealth physical activity (promotion) behaviour change intervention app and dual intra-interpersonal socioecological contexts, and reference citations.

*Table Appendix K.3: Interdisciplinary Collaborative Process Steps and Activities: Detailed Descriptions with Examples and References [Source: Researcher's own construction, informed by critical analysis findings (Chapter 6), literature chapters (Chapters 3 and 4) and additional literature sources]*

| **Interdisciplinary Collaborative Process Step Number and Title** | |
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| **Process Step Description** | **Process Step Activities and Descriptions** |
| **Step 1: Project and Team Formalisation** | |
| The mHealth intervention app project and interdisciplinary team are established and formalised. Business, interdisciplinary process plan, common knowledge base and partnership agreements are formalised. | • Develop a mHealth intervention project plan<br>• Develop a mHealth intervention business plan and model (including business model, monetisation model, competitor analysis, consumer market analysis, marketing model) (#2; #12, #16; Nieborg, 2016; Francis, 2017)<br>• Elect a Team Leader (*"Actors"* Component)<br>• Elect a Project Manager (*"Actors"* Component)<br>• Elect Primary Empirical Study Facilitators (*"Actors"* Component)<br>• Establish an interdisciplinary collaborative team (*"Actors"* Component) involving relevant heterogeneous communities of practice<br>• Complete the *Interdisciplinary Collaborative Team Member and Perspectives Template* (Appendix J.2) and follow the *Guideline Recommendations for High-Performing Interdisciplinary Collaborating Teams* (Appendix J.3).<br>• Identify relevant third party stakeholders (*"Actors"* Component) and formalise partnership agreements<br>• Identify the potential end user target population group (*"Actors"* Component)<br>• Co-develop and outline a shared interdisciplinary collaborative process plan (*"Process"* Component) (#9; #12)<br>• Co-develop a common shared syntactic and semantic knowledge base (e.g. lingua franca; common glossary) (#1; #7; #17; #18; #19)<br>• As an interdisciplinary collaborating team, co-develop and formalise project, business and team documentation, including descriptions for roles, responsibilities, boundaries, team positioning and decision-making power, and outlines for communication, cooperation, coordination and collaboration informatic and work arrangements, processes and practices. |
| **Step 2: Problem Understanding** | |
| The health problem, target health behaviour, target population group, digital platform and contextual factors are assessed, explicated and co-defined. | • Define the health problem (in behavioural terms, e.g. insufficient physical activity) (Chapter 3; #9; #11)<br>• Define the target context and target population group (*"Actors"* Component) (consumer-centred in relation to the dual intra-interpersonal socioecological levels of health promotion (SEM model; Chapter 3; #5; #7; #9)<br>• Select the (broad) target behaviour (e.g. to reduce physical inactivity by increasing walking) (Chapter 3; #5; #7; #9; #11)<br>• Specify the (refined) target behaviour (e.g. to reduce physical inactivity by walking 10 000 steps a day) (Chapter 3; Global Recommendations on Physical Activity, WHO, 2010b; 2020c); #9; #11; #20)<br>• State the broad intervention aim in behavioural terms and digital terms (e.g. to reduce physical inactivity of young adults aged 13-19 in South Africa by increasing walking by 10 000 steps a day, and deliver intervention through a mHealth behaviour change consumer app) (#1; #5; #7; #8)<br>• Conduct health and target behaviour and target population group needs assessments (including psychosocial needs, #13)<br>• Conduct a contextual inquiry (#2; #16)<br>• Review and identify at-risk factors and modifiable determinants (#1; #13)<br>• Co-create a shared Logic Model of the Problem (#1; #5; #13)<br>• Conduct a digital technology (app) operational needs and demands assessment (Chapter 4; #2; #5; #19)<br>• Conduct technological state-of-the-art (SOTA) and technological readiness level (TRL) assessments (Chapter 4; #19; Kowatsch, et al., 2019)<br>• Describe human factors and user interaction and experience preferences (Chapter 4; #1; #5 to #12; #18; #19; Kowatsch, et al., 2019)<br>• Co-create and document a co-definition (shared understanding) of the problem (in terms of health behaviour, target behaviour, target population, digital (app) technology and context) (Chapter 5; #9; #12; #14; #15). |

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| | • For a mHealth physical activity behaviour change intervention app project, all Step 2 activities can be supported by referencing: Chapter 3; Chapter 4; #5; #7; #9; #11; Global Recommendations on Physical Activity (WHO, 2010b; 2020c); King, et al., 2013; 2016 (using #20); Lee, et al., 2018 (using #8); Matthews, et al., 2017 (using #2, #4 and #13); Simons, et al., 2018 (using #1); Wang, et al., 2017 (using #17). |
| **Step 3: Theoretical and Conceptual Base Solution Development** | |
| **Step 3.1: Theoretical Base** | |
| The health behaviour change intervention and digital technology (and user interaction) aims, objectives and scope are co-defined and specified. | • State the health (promotion) behaviour change intervention (clinical) aims (in terms of determinant change and effectiveness measures) (Chapter 3; #7)<br>• State the health behavioural outcomes (e.g. to engage in aerobic exercise for 30 minutes a day) (Chapter 3; #1; #5; WHO, 2010b; 2020c)<br>• State the digital technology (app) and user interaction/experience (usage) aims (in terms of digital app elements and app user engagements) (Chapter 4; #7)<br>• Specify the mHealth intervention app theme, subthemes and scope (i.e. the intervention brand, e.g. "we walk together" for a mHealth physical activity consumer app) (#1)<br>• Specify the performance objectives for the health behaviour change intervention, as specific observable and actionable subsets of the target behaviour (e.g. create an action plan with realistic goals to achieve physical activity pattern) (Chapter 3; #1; #5; #19)<br>• Specify the performance objectives for user interaction, as specific observable and actionable subsets of user interaction behaviour (e.g. user is motivated to interact with virtual coach as physical activity personal trainer) (Chapter 4; #19; Clark, et al., 2017; Kowatsch, et al., 2019)<br>• Select intra-interpersonal behavioural change determinants and correlates (theory-based and evidence-based physical activity determinants and correlates e.g. self-efficacy, motivation; perceived competence, perceived behavioural control, social support (Figures 3.4 and 3.5, Chapter 3; Appendix B; #1; #5; #7; #13; #15; #18; #19; Aleksovska, et al., 2019; Mötteli and Dohle, 2020; Rhodes, et al., 2020)<br>• Specify change objectives (i.e. the actionable changes on determinants and correlates in order to meet performance objectives) (e.g. to feel positive about being more physically active; to feel positive about self-monitoring walking activity) (Chapters 3 and 4; #1; #5; #19)<br>• Co-create change objective matrices for health behaviour change intervention (#1; #5; #19)<br>• Co-create change objective matrices for user interaction (#19)<br>• Co-create a shared Logic Model of Change (#1; #5; #13, #14)<br>• Co-develop a mHealth intervention app value map (Chapter 4; #2; #5; #19)<br>• Start co-creating mHealth stories (Ben-Zeev, et al., 2015)<br>• Co-develop a theoretical base solution document for the mHealth (physical activity) behaviour change intervention app (Chapter 5; #5; #7; #14; #15) |
| **Step 3.2: Conceptual Base** | |
| The theory and evidence-based strategies, methods, standards and guidelines are specified as practical strategy applications. The shared visions of the theoretical base and conceptual base are co-developed. | • Identify and select relevant theory-based and evidence-based mechanisms of change/action (behavioural change methods) and behavioural change techniques (BCTs) using theoretical models and taxonomies (e.g. goal setting, self-monitoring, prompts/cues, habit formation) [effective BCTs for mHealth physical activity apps identified in: Chapters 4 and 6; CALO-RE (Michie, et al., 2011); BCT v1 (Michie, et al., 2013); King, et al. (2013; 2016) (using #20); TBCM (Kok, et al., 2016); Matthews, et al. (2017) (using #3); Wang, et al. (2017) (using #17); Lee, et al. (2018) (using #8); Simons, et al. (2018) (using #1); Truelove, et al. (2020) (using the BCW)]<br>• Incorporate appropriate evidence-based standards (e.g. CONSORT-EHEALTH, mERA)<br>• Incorporate appropriate evidence-based codes of practice (e.g. PAS 277:2015 – quality criteria for health and wellness apps) (British Standards Institution, 2015)<br>• Integrate relevant guidelines and recommendations (e.g. Global Recommendations on Physical Activity, WHO, 2010b; 2020c) (#3; #4; #9)<br>• Co-create common behavioural science summary sheets (#20)<br>• Identify and select appropriate gamification techniques, and link them with the selected BCTs (e.g. points system for achieving physical activity goals – links with goal setting BCT) (#9; #10; #18; van Dyck, 2017)<br>• Identify and select suitable persuasive technology, health behavioural change support system and persuasive systems design principles, and link them with the selected BCTs (e.g. self-monitoring, rewards, praise, reminders, personalisation, tailoring, social comparison, competition for physical activity) [Chapters 4 and 6; #2; #10; #17; #19; FBM (Fogg, 2009); PSDM (Oinas-Kukkonen and Harjumaa, 2009); Hamper, et al. (2016); Win, Roberts and Oinas-Kukkonen (2018); Almutari and Orji (2019)] |

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| | • Conceptually translate and operationalise selected behaviour change methods, BCTs, standards, codes, guidelines, gamification techniques and persuasive principles into practical strategy applications. Co-create lists and matrices to link theories, concepts and practical applications (#1; #4; #5; #19)<br>• Co-formulate guiding principles (intervention core design objectives and key features) (#13)<br>• Revise co-created mHealth stories (Ben-Zeev, et al., 2015)<br>• Clarify understanding of target population end users' app user interaction/experience design preferences<br>• Co-develop high-level diagram of mHealth intervention app components (techniques and practical strategies), sequence and user flow (#1; #5; #7; #9)<br>• Co-produce a shared vision (common solution) document for the mHealth (physical activity) behaviour change intervention app by updating and refining the co-developed theoretical base solution document to incorporate the conceptual base solution (Chapter 5; #14; #15 #16) |
| **Step 4: Instantiated Conceptual and Technological Solution Design** | |
| The theoretical and conceptual base solution is translated and operationalised into an instantiated co-conceptualised and co-developed digital platform mHealth intervention app design solution. | • Collaboratively generate and prioritise creative and innovative conceptual mHealth intervention app design ideas (#1; #8; #15; #16; #20; Francis, 2017)<br>• Translate and operationalise the practical strategy applications (behaviour change methods, BCTs, standards, codes, guidelines, gamification techniques and persuasive principles) into digital and technical (app) features (e.g. reward BCT and persuasive design principle operationalised as a virtual sea creature in physical activity *Starfish* app (Paul, et al., 2017), as virtual flowers and butterflies in *UbiFit Garden* physical activity app (Consolvo, et al., 2008), as virtual badges in *SportyPlanner* physical activity app (Vaquero, 2016)) [additional mHealth physical activity app examples discussed in Chapters 4 and 6; #5 to #12; King, et al. (2013; 2016) (using #20); Matthews, et al. (2017) (using #3); Wang, et al. (2017) (using #17); Lee, et al. (2018) (using #8); Simons, et al. (2018) (using #1); Geuens, et al. (2016); PSDM (Oinas-Kukkonen and Hajumaa, 2009); Dyadic Lenses (Geuens, et al. (2019)]<br>• Co-create motivational frames (#20)<br>• Further develop and revise co-created mHealth stories (Ben-Zeev, et al., 2015)<br>• Specify BIT elements (the software interface app design features) (e.g. app notification prompts user to plan physical activity schedule; app screen provides user with dashboard and graph of physical activity over last seven days in relation to goals set and achievements) (Chapters 4 and 6; #5; #7; #17)<br>• Define mHealth intervention app information architecture (Francis, 2017)<br>• Define technical characteristics (Chapters 4 and 6; #5; #7; #17; DHI Taxonomy (Wang, et al., 2017; 2019)]<br>• Describe and illustrate workflow(s) (on BIT elements and JITAIs) (#5; #7; #16; #17; Francis, 2017; Direito, et al., 2019)<br>• Co-create BIT-Tech framework and diagram (#5; #7; #17)<br>• Co-create complex (translation and operationalisation) instantiation matrices (tables linking theoretical and conceptual base solution (from Step 3) to the conceptual and technological design solution (Step 4) (#5)<br>• Co-create a shared Final mHealth Intervention App Logic Model (#1; #5)<br>• Co-design and co-produce low-fidelity conceptual instantiation mHealth intervention app design solutions (e.g. sketches, diagrams, workflows of conceptual instantiation design ideas) (#5; #7)<br>• Collaboratively update and refine detailed mHealth intervention app design instantiation components (techniques, practical strategies, app design features), sequence, user flow(s) and workflows (#1; #5; #7; #9; #17)<br>• Collaboratively update and refine guiding principles (#13)<br>• Co-develop a shared design vision (common design solution) document outlining and detailing the conceptual and technological mHealth behaviour change intervention app design solution (Chapter 5; #5; #7; #14 to #17)<br>• Co-develop a preliminary interdisciplinary collaborative team plan for guiding the instantiated concrete solution design and development process (to be carried out in Step 5) |
| **Step 5: Instantiated Concrete Solution Design and Development** | |
| Iterative prototyping and usability design-test-refine cycles are performed to produce a co-designed and co-developed (nearly fully functional) MVP alpha mHealth intervention app. | • Review and formalise the interdisciplinary team's collaborative instantiated concrete solution design and development process and work plan (outlining agreed upon communication, cooperation, coordination, negotiation and collaboration informatic and work arrangements, processes and practices) (e.g. prototyping plan for iterative developing-testing-refining MVP alpha app) (Chapters 5 and 6; Ben-Zeev, et al., 2015; Sucala, et al., 2019)<br>• Collaboratively conduct a series of iterative low-, medium- and high-fidelity prototyping cycles to co-develop and co-refine the MVP alpha mHealth behaviour change intervention app prototypes. Prototyping activities may include the interdisciplinary team members, experts, stakeholders and/or end users, *"Actors"* Component) (low- |

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| | to medium-fidelity app prototype examples: sketches, storyboards, manual and/or digital user interface screen mock-ups, flow diagrams, app screen maps) (high-fidelity app prototype examples: 2D and 3D computer simulations, basic functional and interactive MVP apps) (Francis, 2017; Kowatsch, et al., 2019; Sucala, et al., 2019)<br>• Collaboratively conduct testing sessions, which may include the interdisciplinary team members, experts, stakeholders and/or end users, *"Actors"* Component). Testing sessions can include usability testing (#2; #4; #8; #9; #11; #14; #16 to #20; Sucala, et al., 2019), user experience testing (#8; #9; #11 to #13; #18 to #20; Sucala, et al., 2019), and alpha testing (#12; Naeem, et al., 2015; Francis, 2017)<br>• Gather testing feedback on the mHealth behaviour change intervention alpha app prototype(s) (pertaining to the app's theories, BCTs, gamification techniques, persuasive design principles, practical strategy applications, operationalised instantiations, software interface design features and functionalities, BIT elements, technical characteristics, workflows, and the overall mHealth app concrete and material solution design)<br>• Co-refine mHealth stories (Ben-Zeev, et al., 2015)<br>• Co-produce shared documentation (throughout Step 5) outlining and detailing the iterative prototyping and testing cycles, along with the protocols, gathered and analysed testing feedback, and the alpha app design solution changes and refinements (Chapter 5; #2; #8; #14; #15; #16)<br>• Collaboratively produce a co-designed and co-developed MVP (near-fully functional) alpha mHealth behaviour change intervention app (app prototype) (#12; Ben-Zeev, et al., 2015)<br>• Co-develop a preliminary interdisciplinary collaborative team plan for guiding the pilot/feasibility testing and beta testing formative evaluation processes (to be carried out in Steps 6.1 and 6.2, respectively) |
| **Step 6: Formative Evaluation** | |
| **Step 6.1: Pilot Testing** | |
| Pilot and feasibility tests are (iteratively) performed to co-produce a refined (fully functional) alpha mHealth intervention app. | • Review and formalise the interdisciplinary team's collaborative pilot testing (formative evaluation) process and work plan (outlining agreed upon communication, cooperation, coordination, negotiation and collaboration informatic and work arrangements, processes and practices) (e.g. pilot testing and feasibility testing plan) (Chapters 5 and 6)<br>• Select appropriate pilot and/or feasibility testing methods, measures and tools [e.g. Health-ITUEM (Brown, et al., 2013) (#11); MARS (Stoyanov, et al., 2015); uMARS (Stoyanov, et al., 2016); CEEBIT (Mohr, et al., 2013)]<br>• Collaboratively conduct pilot testing and/or feasibility testing sessions on the MVP alpha mHealth behaviour change intervention app prototype. Pilot/feasibility testing sessions may be iterative, and may include the interdisciplinary team members, experts, stakeholders and/or end users (*"Actors"* Component) (#6; #8 to #12; Ben-Zeev, et al., 2015; Eldridge, et al., 2016; Lyles, et al., 2017)<br>• Co-produce shared documentation (throughout Step 6.1) outlining and detailing the (iterative) pilot and/or feasibility testing cycles, along with the protocols, gathered feedback and the MVP alpha app design and development solution changes and refinements (Chapter 5; #2; #8; #14; #15; #16)<br>• Collaboratively produce a co-developed and co-refined fully functional alpha mHealth behaviour change intervention app (app prototype) (#12)<br>• Collaboratively co-refine the preliminary interdisciplinary collaborative team plan for guiding the beta testing formative evaluation process (to be carried out in Step 6.2) |
| **Step 6.2: Beta Testing** | |
| Beta tests are (iteratively) conducted to co-produce a refined mHealth intervention app as a beta release candidate. | • Review and formalise the interdisciplinary team's collaborative beta testing (formative evaluation) process and work plan (outlining agreed upon communication, cooperation, coordination, negotiation and collaboration informatic and work arrangements, processes and practices) (e.g. beta testing plan) (Chapters 5 and 6)<br>• Select appropriate beta testing methods, measures and tools (applicable to the mobile platform). Beta testing software can be free, paid or crowdsourced (e.g. Instabug; Ubertesters; TestFairy; TestFlight; Firebase Crashlytics; Microsoft Visual Studio App Centre)<br>• Collaboratively conduct beta testing sessions on the fully functional alpha mHealth behaviour change intervention app prototype. Beta testing sessions may be iterative, and can include real world end users as representatives of the target population group (*"Actors"* Component) (#12; Naeem, et al., 2015; Francis, 2017; Birrell, et al., 2019; Sucala, et al., 2019; Teo, et al., 2019)<br>• Co-produce shared documentation (throughout Step 6.2) outlining and detailing the (iterative) beta testing cycles, along with the protocols, gathered feedback and the beta app design solution changes and refinements (Chapter 5; #2; #8; #14; #15; #16)<br>• Collaboratively produce a refined mHealth behaviour change intervention app as a beta release candidate (#12) |

| Step 7: Deployment | |
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| A deployment plan and business plan are co-produced for the mHealth intervention app's public commercial release. The beta release candidate is deployed to consumer app market stores. | • Collaboratively co-produce a mHealth intervention app deployment plan for publicly deploying the beta release candidate "in the wild" real world setting on the commercial consumer app market (e.g. Google Play, Apple Store). Include a deployment strategy and app rollout plan, web API server plan, app store submission material. Address deployment considerations: mobile operating system (e.g. Android, iOS)); web API server and back-end cloud server for web or hybrid apps (e.g. Amazon Web Services, RackSpace); mobile telecommunication infrastructures and carriers; commercial mobile service providers (e.g. Vodacom, MTN, Telkom in South Africa); commercial consumer app store policies (e.g. Google Play, Apple Store). Deployment may include third party stakeholder involvement (*"Actors"* Component) (Ben-Zeev, et al., 2015, p2; Francis, 2017; Tozzi, 2017; Taylor, 2018; Othman, Ugap and Rahman, 2019; Kowatsch, et al., 2019; Sucala, et al., 2019)<br>• Collaboratively review and update business plan, model and documentation. Include the monetisation model (e.g. traditional paid apps, subscription payments, in-app purchases, premium features, ad-revenue, selling user data); competitors analysis and plan (e.g. app installations, ratings, reviews, developer histories); and marketing plan. Plans may include third party stakeholder involvement (*"Actors"* Component) (Naeem, et al., 2015; Nieborg, 2016; Francis, 2017; Kowatsch, et al., 2019)<br>• Collaboratively co-produce deployment plan and deployment documentation, and co-review and update the business plan, business model, monetisation model and business documentation. |
| **Step 8: Summative Evaluation** | |
| Summative evaluations are conducted on the beta release candidate to measure its quality, engagement, efficacy and effectiveness over time. A refined mHealth intervention app is co-produced and released on commercial consumer app market stores. | • Collaboratively co-produce a summative evaluation plan to evaluate the app's user engagement and intervention efficacy and effectiveness over a period of time [timeframe ranges e.g. 1 month (#11); 3 to 6 months (#15); 12 months (#13; #15); 2 to 5.5 years (Piantadosi, 2017; Pham, Wiljer and Cafazzo, 2016)]<br>• Collaboratively identify and select post-deployment summative evaluation methodologies. Methodologies can be traditional (e.g. robust gold standard RCTs) (#1 to #4; #6; #8; #11 to #13; #17; #19; #20) or newly adapted (e.g. evidence-advanced analytics, intervention evaluation methods, optimisation methodologies (MOST), machine learning, validation testing methodologies) (#5 to #13; #15; #17; #19; Kowatsch, et al., 2019; Othman, Ugap and Rahman, 2019; Sucala, et al., 2019)<br>• Select and outline appropriate post-deployment evaluation user app engagement methods and tools (may involve third party stakeholders and end users, *"Actors"* Component) [e.g. Google Analytics for Mobile Apps; game analytics (#18); Health-ITUEM (Brown, et al., 2013) (#11); MARS (Stoyanov, et al., 2015); uMARS (Stoyanov, et al., 2016); CEEBIT (Mohr, et al., 2013)] (Chapter 4; #12; #18; Nieborg, 2016; Francis, 2017; Taylor, 2018; Othman, Ugap and Rahman, 2019; Sucala, et al., 2019)<br>• Select and outline appropriate post-deployment evaluation intervention effect health behaviour methods and tools (may involve third party stakeholders and end users, *"Actors"* Component) [e.g. APEASE Criteria (Michie, Aktins and West, 2014) (#14); Health-ITUEM (Brown, et al., 2013) (#11); CEEBIT (Mohr, et al., 2013); MOST method (Collins, Murphy and Stretcher, 2007; Collins, 2018) (#3; #17), SMART method (Collins, Murphy and Stretcher, 2007) (#17); TIPs method (Mohr, et al., 2015); ABACUS (McKay, Slykerman and Dunn, 2019); RE-AIM (Glasgow, et al., 2019)] (Chapter 4; Kowatsch, et al., 2019; Sucala, et al., 2019)<br>• Select and define appropriate post-deployment evaluation user app engagement measures and metrics (in alignment with usage aims). Measures can be (1) objective (e.g. consumer app product analytics, test analytics) and/or (2) subjective (e.g. end user feedback, app store reviews and ratings). Methods can be qualitative (e.g. interviews, focus groups) and/or quantitative (e.g. surveys, questionnaires, statistical analyses) (Chapter 4; #5 to #12; #15; #17 to #20; Taylor, 2018; Kowatsch, et al., 2019; Sucala, et al., 2019)<br>• Select and define the post-deployment evaluation intervention effect measures and metrics (in alignment with clinical aims and health behavioural outcomes) [e.g. increases in physical activity behaviour; geolocation data; anthropometric measurements (BMI, body fat percentage, weight loss, waist-to-hip circumference ratio)] (Chapters 3 and 4; #1 to #9; #11 to #13; #15; #17 to #19; Sucala, et al., 2019)<br>• Select appropriate reporting guidelines for summative evaluations [e.g. CONSORT-EHEALTH (Eysenbach, 2013); mERA (Agarwal, et al., 2016)] (Kowatsch, et al., 2019)<br>• Collaboratively conduct summative evaluations on the mHealth intervention app beta release candidate (may involve the interdisciplinary team members, third party stakeholders and end users, *"Actors"* Component)<br>• Collaboratively co-produce an updated and improved mHealth behaviour change intervention consumer app based on the summative evaluation findings (#12)<br>• Co-develop and co-produce shared documentation (throughout Step 8) outlining and detailing the conducted summative evaluations, along with the protocols, ethics, methodologies, tools and methods, measures and metrics, reporting guidelines, evaluation feedback, data and game analytics, any refinements and updates to the refined commercial mHealth behaviour change intervention consumer app (Chapter 5; #2; #8; #14; #15; #16) |

| Step 9: Post-Market Release Surveillance and Continuous Improvement | |
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| Subsequent to the mHealth intervention consumer app's public release on the commercial app market, continuous tracking, monitoring, maintenance, testing and improvement updates are executed over the remaining lifespan of the app. Business and monetisation analyses are performed, and project reports are published and disseminated. | • Collaboratively co-produce post-market surveillance and continuous improvement strategies and plans for the remaining lifespan of the mHealth behaviour change intervention consumer app on the commercial app market (e.g. Google Play and Apple App Stores). Strategies and plans should cover continuous tracking and monitoring; continuous testing and delta testing; continuous deployment and delivery; continuous summative evaluation; continuous maintenance; and continuous improvement and updates (#12; Francis, 2017; Tozzi, 2017; Taylor, 2018; Mala, et al., 2019; Sucala, et al., 2019) and continuous traceability for app versioning (e.g. v4.1.5, v4.2.1) (Lin, et al., 2014; Othman, Ugap and Rahman, 2019)<br>• Collaboratively co-produce additional post-market strategies and plans, including: the business plan and model; finance management and the monetisation plan and model; product plan; and consumer marketing strategy and model (#12; Nieborg, 2016; Francis, 2017; Mala, et al., 2019; Kowatsch, et al., 2019; Sucala, et al., 2019).<br>• Identify, select and utilise appropriate continuous tracking and monitoring surveillance tools. Tools can measure objective or subjective tracking. (Objective tool examples: Google Analytics for Mobile Apps; Prometheus; Sentry; Appsee; Apptentive; big data analytics; game analytics (#18); biosensors and geolocations) (Subjective tool examples: consumer app store user reviews and ratings (stars); error reporting; surveys; questionnaires) (#4; #12; Francis, 2017; Tozzi, 2017; Taylor, 2018; Sucala, et al., 2019)<br>• Identify, select and utilise appropriate continuous testing, continuous integration and continuous improvement tools (will involve DevOps and end users; may involve multi-disciplinary team, third-party stakeholders – Actor Component) (tools e.g. Google Analytics for Mobile Apps; Continuous Testing Cloud; Prometheus; Microsoft Visual Studio App Center; Appsee; Apptentive; Experitest; QuerySurge; Jenkins) (#12; Francis, 2017; Taylor, 2018; Mala, et al., 2019; Sucala, et al., 2019)<br>• Collaboratively conduct continuous post-market release surveillance activities on the publicly published mHealth behaviour change intervention app (informed by the post-market surveillance and continuous improvement strategies and plans, and by using the selected tools and methods). Activities can include DevOps, end users, the interdisciplinary team members and third party stakeholders (*"Actors"* Component)<br>• Conduct continuous testing, delta testing, continuous fixes (e.g. crashes), continuous improvements (performance and new features) and continuous updates to the mHealth intervention consumer app. Activities can include DevOps, end users, the interdisciplinary team members or third party stakeholders (*"Actors"* Component). Keep up-to-date on advancements in mobile digital technology, app store policies and standards, software operating system updates (e.g. Android, iOS). Use innovative and creative ideas and solution designs to enhance the app's end user engagement and intervention effectiveness. Aim to strike a balance between speed vs quality and managing the back-end and front-end during the continuous testing and improvement activities (#12; Mohr, et al., 2013; Ben-Zeev, et al., 2015; Naeem, et al., 2015; Francis, 2017; Taylor, 2018; Centercode, 2019a; Centercode, 2019b; Mala, et al., 2019; Sucala, et al., 2019)<br>• Conduct frequent reviews and updates to the business, finance and monetisation strategies and models, the product strategy and plan, and the consumer marketing strategy and model (Nieborg, 2016; Francis, 2017; Mala, et al., 2019; Kowatsch, et al., 2019; Sucala, et al., 2019)<br>• Co-produce shared documentation (throughout Step 9 and for the remainder of the app's lifespan) outlining and detailing the post-market surveillance and continuous improvement strategies, plans and activities. Co-produce supplementary documentation detailing the various protocols, ethics, methodologies, tools, versioning, data and game analytics, and all of the feedback findings and app improvements, fixes, refinements and updates (#1; #8; #16; Chapter 5; Mala, et al., 2019; Sucala, et al., 2019)<br>• Co-produce, publish and disseminate mHealth intervention app project reports and findings over time (share across academic, industry, public and community spheres) (#8; #16) |

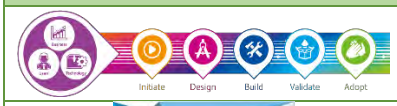
# Appendix L.1 (Chapter 7): Boundary Object and Supporting Artefact Example Icons in Figure 7.8

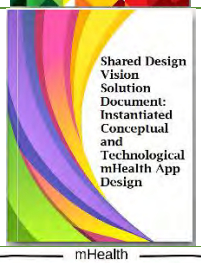
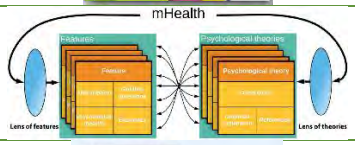
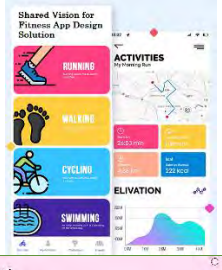
## 7.5.1 Boundary Objects and Supporting Artefacts: A Detailed Perspective: Boundary Object and Supporting Artefact Example Icons in Figure 7.8

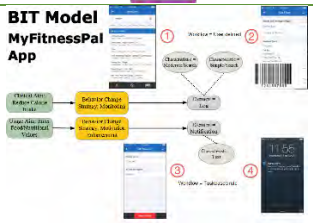
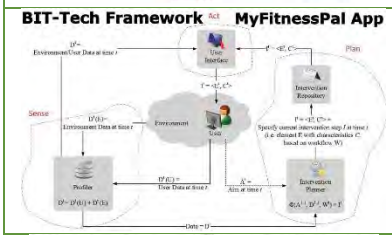
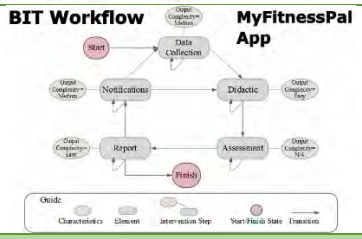
Figure 7.7 provides a clipping of the "*boundary objects and supporting artefacts*" component from Figure 7.2, pertaining to the pragmatic artificial and sociomaterial aspect of the proposed framework. In honing in on the objects component of Figure 7.2, Figure 7.8 presents a more detailed perspective of the categories and types of "*boundary objects*" and "*supporting artefacts*" employed, utilised and created by interdisciplinary team members when carrying out process steps and knowledge sharing practices in mHealth (physical activity) behaviour change intervention app projects. The object and artefact example illustrations in Figures 7.7 and 7.8 are not exhaustive or strictly prescriptive (Appendix L.1). Boundary objects are classified into three categories: (1) "*primary*", (2) "*secondary*", and (3) "*tertiary*". Each category comprises two types of boundary object: (1) "*design*" or (2) "*general*". Supporting artefacts are grouped into three categories: (1) "*supporting methods*", (2) "*supporting guidelines, standards and codes of practice*", and (3) "*other supporting artefacts and materials*".

Table Appendix L.1 clearly illustrates and identifies all of the boundary object and supporting artefact example icons provided in Figure 7.8. The titles assigned to the boundary objects' and supporting artefacts' categories and types are informed by the critical theoretical analysis findings (Chapter 6, Sections 6.5.3 and 6.5.5), tri-composite theoretical framework literature (Chapter 5), relevant doctoral dissertations (such as Bertelsen, 1998; Abraham, 2015; Melville-Richards, 2015; Filip, 2016; French, 2016), and other literature publications (such as Bertelsen, 2000; Garrety and Badham, 2000; Nicolini, Mengis and Swan, 2012; Huvila, et al., 2017; Matilainen, et al., 2018). Many of the boundary object and supporting artefact example icons have been designed and adapted by the researcher to suit the mHealth physical activity behaviour change intervention app context.

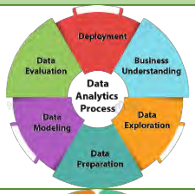
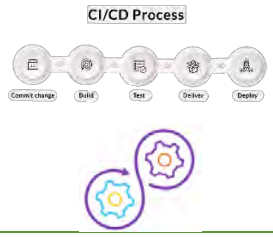
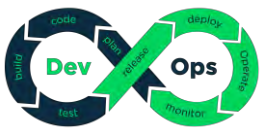
*Table Appendix L.1: Boundary Object and Supporting Artefact Example Icons in Figure 7.8 [Source: Researcher's own construction]*

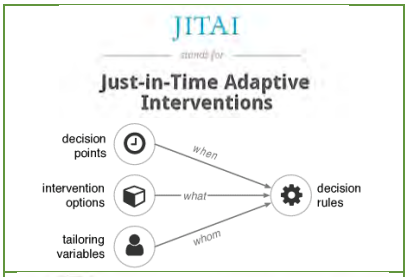
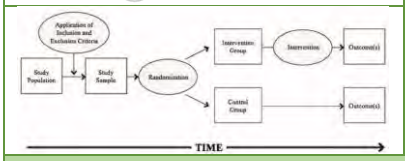
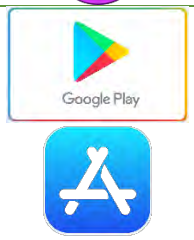
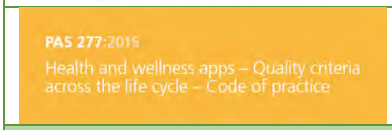
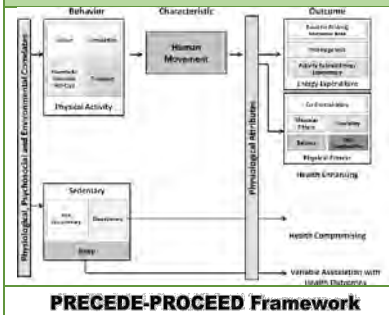
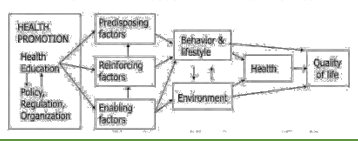
| Boundary Object or Supporting Artefact Category and Type | |
|---|---|
| **Object or Artefact Icon** | **Object or Artefact Title Description** |
| **Primary Design Boundary Objects** | |
|  | mHealth (physical activity) behaviour change intervention app prototypes (early and final product versions) |
|  | mHealth (physical activity) behaviour change intervention app wireframes, user flows (user interaction and engagement) and component (intervention) workflows |
|  | mHealth (physical activity) behaviour change intervention design interface medium-fidelity screen mock-ups |
|  | mHealth (physical activity) behaviour change intervention design interface high-fidelity screen mock-ups |
|  | mHealth (physical activity) behaviour change intervention app prototypes (alpha versions) |
|  | mHealth (physical activity) behaviour change intervention app prototypes (beta versions) |
|  | mHealth (physical activity) behaviour change intervention app prototypes (MVP versions) |
| **Secondary Design Boundary Objects** | |
|  | Shared interdisciplinary collaborative process (outlined and particularised by interdisciplinary collaborating team to suit mHealth intervention app project context and product objectives) |
|  | Co-produced shared collaborative design teamwork documentation, outlining details pertaining to the shared design, development and evaluation processes, informatic and work arrangements, process activities and practices (Step 1 of *Interdisciplinary Collaborative Process*) |

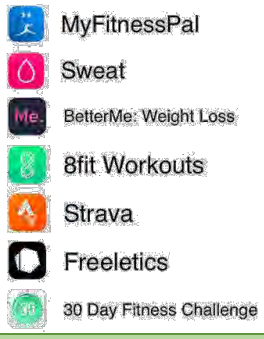
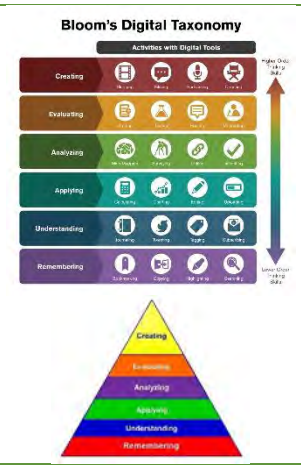
| | |
|---|---|
|  | Co-produced shared vision solution documentation, detailing the theoretical base solution for the mHealth (physical activity) behaviour change intervention app (Step 3.1 of *Interdisciplinary Collaborative Process*) |
|  | Co-produced shared design vision solution documentation, detailing the instantiated conceptual and technological mHealth (physical activity) behaviour change intervention app solution design (Step 4 of *Interdisciplinary Collaborative Process*) |
|  | *Dyadic Lenses for the Motivational Design of mHealth Behaviour Change Intervention Apps* (Approach #10) |
|  | Graphical user interface illustrations of the shared vision for the mHealth (physical activity) behaviour change intervention app design solution, informing the app's development activities |
|  | Design process toolkits to support design, development and evaluation activities, for example the *Design Thinking Workshop Toolkit* |
| **Tertiary Design Boundary Objects** | |
|  | Computer-aided software for designing, developing and formatively testing low-, medium- and high-fidelity mHealth (physical activity) behaviour change intervention app prototypes, storyboards, user flows, workflows, diagrams and illustrations used during the process |
|  | All various types of collaborative design, development and formative testing supporting objects and artefacts, for example tablets, prototyping software, mobile devices, cameras and video recorders, pens, highlighters, scissors, timers, glue, rulers, et cetera |
|  | Manual design, development and formative testing stationary |
|  | Design, development and formative testing prototyping software |
|  | Manuals, guidelines and documentation for guiding and supporting collaborative design, development and formative testing activities |

| | |
|---|---|
|  | Books and notes for guiding and supporting collaborative design, development and formative testing activities |
|  | Creative and artistic materials that support collaborative design, development and formative testing activities |
| **Primary General Boundary Objects** | |
|  | Co-produced shared process map detailing the interdisciplinary collaborative process steps and activities (outlined and particularised by interdisciplinary collaborating team to suit mHealth intervention app project context and product objectives) |
|  | mHealth (physical activity) behaviour change intervention app user flows and maps detailing the technical BIT element characteristics and workflows |
|  | mHealth (physical activity) behaviour change intervention app technical drawings and specifications |
|  | mHealth (physical activity) behaviour change intervention app *BIT Model* (Approach #7), *MyFitnessPal* app example |
|  | mHealth (physical activity) behaviour change intervention app *BIT-Tech Framework* (Approach #7), *MyFitnessPal* app example |
|  | mHealth (physical activity) behaviour change intervention app *BIT Workflow* (Approach #7), *MyFitnessPal* app example |
| **Secondary General Boundary Objects** | |
|  | Co-produced shared interdisciplinary collaborative team documentation, outlining the roles, responsibilities, positions, power dynamics and boundaries of each team member (Step 1 of *Interdisciplinary Collaborative Process*) |
|  | Co-produced shared mHealth intervention app project documentation (Step 1 of *Interdisciplinary Collaborative Process*) |

| | |
|---|---|
|  | Co-produced shared business documentation, including business strategies and models, financial and monetisation strategies and models, product strategy, and consumer marketing strategy and model (Steps 1 and 9 of *Interdisciplinary Collaborative Process*) |
|  | Co-produced shared reports and documentation, can be in terms of the project, problem understanding, theoretical and conceptual base solution development, instantiated conceptual and technological solution design, formative evaluation, deployment, summative evaluation, and post-market release surveillance and continuous improvement activities (Steps 1 to 9 of *Interdisciplinary Collaborative Process*) |
|  | Co-produced shared checklists |
|  | Shared frameworks and models, for example the *Behaviour Change Wheel (BCW)* |
|  | Shared taxonomies, for example the *CALO-RE*, *BCT v1* and *DHI* taxonomies |
|  | Co-produced shared glossaries, such as lingua franca |
|  | Co-produced shared excel documentation |
|  | Co-produced shared documentation and manuals |
|  | Co-produced shared forms, templates and patterns |
| **Tertiary General Boundary Objects** | |
|  | Material and supporting infrastructure used by the interdisciplinary collaborating team during the mHealth intervention app project, for example the workspace |
|  | Material and supporting infrastructure used by the interdisciplinary collaborating team during the mHealth intervention app project, for example the conference and meeting rooms |

| | |
|---|---|
|  | Material and supporting infrastructure used by the interdisciplinary collaborating team during the mHealth intervention app project, for example the buildings and offices |
|  | Digital technology, computer and device artefacts and software used by the interdisciplinary collaborating team during the mHealth intervention app project, for example desktop computers, laptops, mobile devices and project software tools |
|  | Project and team planning infrastructure, materials and software tools, for example manual and virtual whiteboards and sticky notes |
|  | Shared PowerPoint presentations and other slide set software |
|  | Project and team communication infrastructure, materials and software tools, for example emails |
| **Supporting Methods** | |
|   | Borrowed and adapted processes and methods from external sources to support specific design, development and evaluation process activities, for example a mobile data analytics process |
|  | Borrowed and adapted processes and methods from external sources to support specific design, development and evaluation process activities, for example the android app development process |
|   | Alpha testing processes and methods borrowed and adapted from external sources |
|   | Beta testing processes and methods borrowed and adapted from external sources |
|   | Continuous improvement and continuous development (CI/CD) processes and methods borrowed and adapted from external sources |
|   | Development and operations (DevOps) processes and methods borrowed and adapted from external sources |

| | |
|---|---|
|  | Just-in-Time Adaptive Intervention (JITAI) processes and methods borrowed and adapted from external sources |
|  | Randomised Controlled Trial (RCT) processes and methods borrowed and adapted from external sources |
| **Supporting Guidelines, Standards and Codes of Practice** | |
|  | Shared guidelines borrowed and adapted from external sources to support various design, development and evaluation process and product activities |
|  | Guidelines and recommendations for physical activity, exercise and training to inform the mHealth (physical activity) behaviour change intervention app's intervention components and content, for example the WHO's *Global Recommendations on Physical Activity for Health* |
|  | Other guidelines and recommendations for physical activity, exercise and training borrowed and adapted from external sources, used to inform the mHealth (physical activity) behaviour change intervention app's intervention components and content |
|  | Mobile consumer market app store guidelines, standards, guidelines and policies for the mHealth (physical activity) behaviour change intervention app's design and development, for example from the Google Play and Apple App Store |
|  | Mobile consumer market app store guidelines, standards, guidelines and policies for the mHealth (physical activity) behaviour change intervention app's design and development, for example Android and Apple *Human Interface Guidelines* |
|  | Codes of practice borrowed and adapted from external sources to support various design, development and evaluation process and product activities, for example the *British Standards Institute PAS 277-2015 Code of Practice for Health and Wellness Apps Quality Criteria* |
| **Other Supporting Artefacts and Materials** | |
|  | Frameworks and models borrowed and adapted from external sources to inform the mHealth (physical activity) behaviour change intervention app's intervention development, for example the *Framework for Physical Activity as a Complex and Multidimensional Behaviour* |
|  | Frameworks and models borrowed and adapted from external sources to support various design, develop and evaluation process activities, for example the *PRECEDE-PROCEED Framework* for informing the app's intervention development |

| | |
|---|---|
|  | Borrowed and adapted business, project, team and product supporting artefacts and materials, for example *The Business Model Canvas* |
|  | Research supporting artefacts and materials, for example research databases |
|  | Research and literature supporting artefacts and materials, for example academic journals and literature publications |
|  | Supporting artefacts and materials used by the team during the mHealth intervention app project that do not directly support design activities, for example stationery and booklets |
|  | Existing physical activity apps that the team can refer to and learn from when designing and developing the mHealth (physical activity) behaviour change intervention app. Existing apps can be commercial or research apps, that is commercially released on consumer market app stores (such as the Google Play and Apple App Stores) or documented in research studies. Examples include: *MyFitnessPal*, *Sweat*, *BetterMe: Weight Loss*, *8fit Workouts*, *Strava*, *Freeletics*, and *30 Day Fitness Challenge* |
| **Additional Knowledge Artefacts** | |
|  | Shared databases as syntactic knowledge artefacts that facilitate and mediate the transfer of knowledge and provide teams with a common language to access, exchange and share data and information. |
|  | Shared library and filing systems that facilitate and mediate the transfer of knowledge and provide teams with a common language to access, exchange and share data and information. |
|  | Shared taxonomies and categorisation tools that facilitate and mediate the transfer of knowledge and provide teams with a common language to access, exchange and share data and information, such as *Bloom's Digital Taxonomy* |
|  | Shared classification, indexed and ordered systems that facilitate and mediate the transfer of knowledge and provide teams with a common language to access, exchange and share data and information. |

# Appendix L.2 (Chapter 7): A Detailed Overview of Boundary Object Core Properties

### 7.5.2.1 Boundary Objects: A Detailed Overview of Boundary Object Core Properties

Interdisciplinary collaborating teams can distinguish between boundary objects from supporting artefacts by recognising whether the artefacts they employ, use and create meet the three core property criteria of boundary objects (Star and Griesemer, 1989; Star, 2010):

1. Interpretive flexibility;
2. The structure of informatic and work process needs and arrangements; and
3. The dynamic between ill-structured and more tailored uses.

Table 7.4 provides a brief description and examples of each core property, informed by boundary object theory (Chapter 5, Section 5.3.2), the critical theoretical analysis findings (Chapter 6, Section 6.5.6) and relevant literature. Appendix L.2 provides more detailed descriptions and example explanations relevant to the mHealth physical activity behaviour change intervention app context.

*Table Appendix L.2: Boundary Object Core Properties*
*[Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6) and relevant literature]*

| Property | Description | Example(s) |
|---|---|---|
| **Interpretive flexibility** | The object provides sufficient flexibility and recognisability across multiple practice communities and contexts by offering a common point of reference around which communication, coordination, cooperation, and collaboration can be mediated and facilitated while respecting and not compromising the diverse perspectives held different interdisciplinary team members. A specific object is interpreted differently by different team members stemming from a heterogeneity of practice communities. | Interdisciplinary collaborating team members may have different interpretations of a *mHealth physical activity behaviour change intervention app prototype* and its encompassing app design features (example in *"Primary Design Boundary Objects"* in Figure 7.8).<br><br>The information systems community, for instance, is orientated towards interpreting app features in terms of instantiated graphical user interface and user experience design elements, whereas the health behavioural intervention community is orientated towards interpreting app features in terms of instantiated intervention components and operationalised health behaviour change techniques. The two practice communities see and interpret the same physical activity app differently, so the mHealth physical activity intervention app prototype offers |

| | | |
|---|---|---|
| | | interpretive flexibly. Furthermore, as a visually represented and interactive design artefact, the app prototype provides a tangible basis for interdisciplinary collaborating team members to explicitly communicate and translate their different interpretations, thus facilitating cooperation, coordination, negotiation and collaboration through and around the object. |
| **The structure of informatic and work process needs and arrangements** | The object sufficiently reflects the necessary information requirements (or needs) and work practices, processes and arrangements to support interdisciplinary team members' cross-community communication, cooperation, coordination and collaboration. The shared material and organisational structure of the object provides an actionable passage point for information and work flows between collaborating team members, without hindering flexibility and innovation. | A common *"interdisciplinary collaborative process"* (proposed framework, main component 2) provides the interdisciplinary collaborating team with the structure of informatic and work process needs and arrangements (example in *"Secondary Design Boundary Objects"* in Figure 7.8).<br><br>The *"interdisciplinary collaborative process"* sufficiently incorporates the necessary information requirements and work process needs and arrangements of all of the heterogeneous collaborating team members (and their respective practice communities). The shared material and organisational structure of the documented process provides an actionable passage point for information and work process flows between the interdisciplinary collaborating team members.<br><br>A *design solution pattern template* of a mHealth physical activity behaviour change intervention app (example in *"Primary Design Boundary Objects"* in Figure 7.8) contains the minimum necessary information and work practices applicable to an app's theoretical and conceptual solution base, instantiated conceptual and technological solution design, and instantiated concrete solution design. The shared material and organisational structure of the design solution template provides a passage point for information and work flows between the interdisciplinary team members. |
| **The a dynamic between ill-structured and more tailored uses (Plasticity)** | The object is plastic enough to tack back-and-forth between providing team members with weakly or fairly unstructured joint (inter-community) use, and strongly or highly structured localised (individual-community) use. In ill-structured form, the object offers a common point of reference for enabling interdisciplinary translation, communication, coordination, cooperation and negotiation in joint collaborative activities. In strongly structured form, the object can be tailored for use within localised and specialised practices and activities. If desired, interdisciplinary team members are able to cooperate without consensus, tacking back-and-forth between localised and generalised forms of the object. | *mHealth physical activity behaviour change intervention app sketches and wireframes* (examples in *"Primary Design Boundary Objects"* in Figure 7.8).<br><br>Sketches and wireframes are plastic enough to tack back-and-forth between offering team members with weakly or fairly unstructured joint (multiple community) use and strongly or highly structured localised (community-specific) use. In ill-structured form, mHealth intervention app sketches and wireframes function as common points of reference for enabling and sharing interdisciplinary team member translation, communication, cooperation and negotiation. In strongly structured form, mHealth app sketches and wireframes can be tailored for use in localised communities, where actors are able to expand on and annotate them in accordance with their specialised knowledge and expertise. If desired, consensus is not necessary when mHealth intervention app sketches and wireframes are utilised in localised community-specific use, yet their generalised and abstract structure remains sufficiently stable and structured for shared use. |

# Appendix L.3 (Chapter 7): A Detailed Overview of the Characteristics of Boundary Objects

### 7.5.2.2 Boundary Objects: A Detailed Overview of the Characteristics of Boundary Objects

***Characteristics of Boundary Objects***

Boundary objects possess key characteristics (attributes or descriptive qualities) that contribute their shared identity, pragmatic value and evolutionary maintenance in practice contexts and design settings (Wenger, 1998; Fong, Srinivasan and Valerdi, 2007; Broberg, 2011; Abraham, 2015). It is important that interdisciplinary teams manage boundary objects in terms of their core properties and characteristics in order to maintain their coherency and utile value across heterogeneous intersecting practice communities (Bowker and Star, 1999; Wohlrab, et al., 2019). Table 7.5 provides a template outlining sixteen characteristics (with examples): *abstractness*; *concreteness*; *plurality*; *neutrality*; *contextualisation*; *malleability*; *modularity*; *standardisation*; *flexibility*; *visualisation*; *accessibility*; *usefulness (or utility)*; *stability*; *annotation*; *up-to-dateness*; and *versioning (or traceability)*. Table Appendix L.3 provides more detailed descriptions and example explanations relevant to the mHealth physical activity behaviour change intervention app context. Some characteristics exist along a continuum where the aim is to strike an adequate equilibrium balance between two respective characteristics, while other characteristics stand independently.

*Table Appendix L.3: Characteristics of Boundary Objects [Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6), Star and Griesemer (1989), Henderson (1991; 1998), Bowker and Star (1999), Carlile (2002), Fong, Srinivasan and Valerdi (2007), Star (2010), Broberg (2011), Erwin, et al. (2014), Abraham (2015), Lopez, et al. (2018), and Wohlrab, et al. (2019)]*

| Characteristic | Description | Example(s) |
|---|---|---|
| **Abstractness and Concreteness** | A boundary object may exist along a continuum from abstract to concrete.<br><br>*Abstractness* serves the interests of all interdisciplinary team members (stemming from heterogeneous practice communities) by providing a common point of reference that includes and highlights the high-level shared commonalities and excludes localised specificities. An abstract object offers high levels of abstract generalisation (and low levels of concreteness), as well as symbolic, conceptual and non-specific representation.<br><br>*Concreteness* allows the interdisciplinary team members to specify their views, interpretations and concerns, and explicitly express their discipline-specific knowledge and practice expertise. A concrete object offers high levels of concreteness (and low levels of abstractness), as well as tangible, material and specific representation. | The *shared vision solution* for a mHealth physical activity behaviour change intervention app provides a high-level abstract and conceptual representation of the interdisciplinary team's common goal (example in *"Secondary Design Boundary Objects"* in Figure 7.8).<br><br>*Shared conceptual and technological solution design instantiation diagrams, sketches, map, flows and document plans* of a mHealth physical activity behaviour change intervention app generally exist on an abstract level. Adding specificities to the design solution instantiations that are informed by specialist discipline-specific knowledge and expertise shifts the artefacts along the continuum away from abstractness towards concreteness. Examples are in *"Primary Design Boundary Objects"*, *"Primary General Boundary Objects"* and *"Secondary Design Boundary Objects"* in Figure 7.8).<br><br>*Detailed instantiated concrete solutions designs and constructed developments* of a mHealth physical activity behaviour change intervention app – in the form of *high-fidelity prototype versions* – further increase the concreteness of the objects (examples in "Primary Design [and] General Boundary Objects" in Figure 7.8).<br><br>A *working mHealth physical activity behaviour change intervention app prototype* – in fully functional, tangible and material form – on a mobile device represents a concrete object (example in *"Primary Design Boundary Objects"* in Figure 7.8). |
| **Plurality and Neutrality** | A boundary object should provide a balance in providing both plurality and neutrality.<br><br>*Plurality* refers to a boundary object that acknowledges, includes, represents and respects the different informatic and work process needs and arrangements of every relevant interdisciplinary team member. Plurality aims to respect and sufficiently incorporate the heterogeneity of views, interpretations, interests and knowledge held by different practice communities.<br><br>*Neutrality* refers to a boundary object that aspires to maintain as much objectivity as possible by acknowledging and covertly stating all applicable political and sociomaterial relational power dynamics. Neutrality helps maintain fairness in status positioning and conflict negotiation and resolution practices. However, no boundary objects can ever be completely neutral since they are "applicable in contexts of relative equality", are "embedded within complicated networks of social relations" and are "located at the nexus of very specific power relations" (Stoytcheva, 2013, p.5). Efforts should nevertheless be made to achieve as much neutrality as feasibly possible. | An interdisciplinary team's shared *"interdisciplinary collaborative process"* (example in *"Secondary Design Boundary Objects"* in Figure 7.8) should adequately acknowledge, include, represent and respect the different informatic and work process needs and arrangements of each member of the interdisciplinary team, and their respective heterogeneous practice communities.<br><br>At the same time, the commonly shared *"interdisciplinary collaborative process"* (example in *"Secondary Design Boundary Objects"* in Figure 7.8) should aim to be as neutral and objective as possible by not favouring or disregarding the status positioning and relational power dynamics of the participating interdisciplinary collaborating team members. |

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| **Contextualisation** | A designated artificially engineered boundary object can be adapted and particularised to fit the specific mHealth intervention app project, and the health behaviour and design problem and situation context in which the interdisciplinary collaborating team members intend to use it. | The *BIT Model*, *BIT-Tech Framework* and *BIT Workflow* (examples in *"Primary General Boundary Objects"* in Figure 7.8) can be adapted and particularised to fit a specific mHealth physical activity behaviour change intervention app project, health and design problem and situation context. Mohr (2013) applies the artificial (engineered) and nominated BIT Model, BIT-Tech Framework and BIT Workflow to *MyFitnessPal*, an international well-known physical activity behaviour change intervention consumer app (available on the commercial app market). |
| **Malleability** | A boundary object can be reviewed, reflected upon, adapted, altered, modified, transformed, reconfigured and revised over time, in response to new informatic requirements and work process needs and arrangements, and newly identified differences, dependencies, interests and novelties. | A *mHealth physical activity behaviour change intervention app prototype* is iteratively reviewed, altered, modified, revised and transformed over time (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). The app is malleable both before and after consumer app market release, subject to prototype design and development revisions beforehand, and subject to continuous improvement, testing and delivery during post-market release. |
| **Modularity** | Specific members of the interdisciplinary collaborating team can tend to particular aspects, components or elements of the boundary object independently from other aspects of the object. Modularity allows team members to focus their specialised knowledge, skills and expertise where and when necessary, without disturbing other team members' use of the boundary object. | Team members residing in the computer sciences community are able to tend to the specific technical details of the mHealth physical activity behaviour change intervention app's design without disturbing team members localised in the other practice communities (example illustration in *"Primary General Boundary Objects"* in Figure 7.8). For instance, app developers, mobile software developers, DevOp engineers and information architects are able to tend to the software (programming) code and information architecture of a (functional) mHealth physical activity behaviour change intervention app without disturbing other team members, such as those residing in the health behavioural intervention, business and product development and persuasive technology communities (Table 7.2). |
| **Standardisation and Flexibility** | A boundary object should provide interdisciplinary collaborating team members with a balance between standardisation and flexibility.<br><br>*Standardisation* refers to the skeleton architecture of an object that should remain sufficiently structured, while *flexibility* allows for malleability, contextualisation, innovation and transformation. | An interdisciplinary team's shared *"interdisciplinary collaborative process"* (example in *"Secondary Design Boundary Objects"* in Figure 7.8) provides a balance between standardisation and flexibility. It was argued and justified in detail in Section 7.4 that the proposed *"interdisciplinary collaborative process"* offers a general and comprehensive – and not a rigid, strict or inflexible – guideline for interdisciplinary team members to refer to, adapt and contextualise to their particular mHealth behaviour change intervention app project. |
| **Visualisation** | A boundary object may rely on ocular graphical, illustrative, virtual or physical material properties and representations, rather than solely verbal or written properties. The (design) boundary object functions as a visual interface between the interdisciplinary collaborating team members by enabling, mediating, supporting and fostering open dialogical and visually expressive exchanges regarding the object's interpretive flexibility and negotiable elements. | *Graphical user interface design sketches* of a mHealth physical activity behaviour change intervention app provide visual illustrations of the app's interface design features (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). The sketches function as design boundary objects and visual interfaces for mediating, supporting and fostering open dialogical and visually expressive exchanges about the app's intended graphical user interface design features. The sketches will also involve the employment and use of creative materials (such as the colour paints, pens or virtual user interface design software examples in *"Tertiary Design Boundary Objects"* in Figure 7.8). |
| **Accessibility** | All of the relevant interdisciplinary collaborating team members should be aware of, informed about and be able to access a boundary object when necessary. Other measures and resources, such as training and guideline application materials, should be available and accessible should team members wish to employ | The *interdisciplinary team's shared documentation* should be available and accessible at all times during a mHealth physical activity behaviour change intervention app project and process (examples in *"Secondary Design Boundary Objects"* and *"Secondary General Boundary Objects"* in Figure 7.8). |

| | | |
|---|---|---|
| | and utilise a boundary object in actionable practice. | A mHealth intervention app project's *guideline recommendations for application and templates* – such as those proposed in the framework's actor component (Section 7.3) and process component (Section 7.4) – should be available and accessible for all of the interdisciplinary team members during the lifespan of the mHealth intervention app project. |
| **Usefulness (or Utility)** | A boundary object should sufficiently satisfy the minimum informatic requirements and work process needs and arrangements of each collaborating practice community. The boundary object should provide the interdisciplinary team members with vague, yet accurate and good enough, content. The value (usefulness and utility) of the boundary object derives from its pragmatic use by the team members in practice contexts and situational settings. No boundary object is universally useful or intricately whole. | The *taxonomies* and *glossaries* created and utilised by the interdisciplinary team should satisfy the informatic requirements and work process needs and arrangements of each team member (examples in *"Secondary General Boundary Objects"* in Figure 7.8). They should provide the interdisciplinary team members with an adequately vague, yet accurate and good enough, shared syntactic and semantic representation of the collaborating practice communities. The value (usefulness and utility) of the taxonomies and glossaries derives from their pragmatic use by team members in practice contexts and situational settings (for instance, when designing and developing the instantiated conceptual and technological solution design of a mHealth physical activity behaviour change intervention app). |
| **Stability** | The skeleton architecture and infrastructure structure and information content of a boundary object should provide a common frame of reference over time, while simultaneously allowing for evolutionary malleability, flexibility, contextualisation, updates and versioning. | The skeleton structure and information content of a project's and team's shared *"interdisciplinary collaborative process"* should remain stable over time, while simultaneously allowing for revisions, updates and versioning changes (example illustration in *"Secondary Design Boundary Objects"* in Figure 7.8). |
| **Annotation** | Interdisciplinary collaborating team members may enrich a boundary object with additional information to provide context of localised and tailored community-specific use. While the abstract and generalised structure and information content of the boundary object remains stable, team members have the option of expanding on and adding local information. | The *interaction user flow diagrams* of a mHealth physical activity behaviour change intervention app will remain stable for common use, but may be annotated with additional information for localised community-specific use (example illustration in *"Primary Design Boundary Objects"* and *"Primary General Boundary Objects"* in Figure 7.8). Team members residing in the information systems and persuasive technology and game development communities (such as mobile app designers, human computer interaction designers and game designers) are likely to expand on and add local information to a mHealth intervention app's interaction user flow diagrams within their specific communities when designing and developing a functional working app (Table 7.2). |
| **Up-to-Dateness** | The informatic requirements and work process needs and arrangements should remain up-to-date. Updates should be timely and communicated to all of the relevant interdisciplinary collaborating team members involved, and the responsibilities and processes for updating should be available. | The *shared design vision solution documentation on the theoretical, conceptual and instantiation app design* should be kept up-to-date (examples illustration in *"Secondary Design Boundary Objects"* in Figure 7.8). Updates to these documents should be timely and should be communicated (and available and accessible) to all members of the interdisciplinary collaborating team. The responsibilities and processes for updating the documentation should be available. |
| **Versioning (or Traceability)** | Changes, revisions and modifications of a boundary object should be chronologically versioned and tracked over its evolution and lifespan. Versioning is generally performed using semantic numerical sequence-based identifiers and chronological references. Any author versioning references enrich traceability of changes, revisions and modifications. | A mHealth physical activity behaviour change intervention app is versioned throughout its alpha and beta development stages (example illustration in *"Primary Design Boundary Objects"* in Figure 7.8). The versioning of an app continues after it has been publicly released on the consumer app market, particularly when minor and major updates are rolled out. Mobile app versioning follows a strict semantic numerical sequence-based identification notation. |

# Appendix L.4 (Chapter 7): A Detailed Overview of the Nature Qualities of Boundary Objects

### 7.5.2.2 Boundary Objects: A Detailed Overview of the Nature Qualities of Boundary Objects

***The Nature of Boundary Objects***

Boundary objects generally exhibit several innate nature qualities throughout their lifespans, which influences the manner in which they behave and the various roles, forms and functionalities they assume when employed and utilised in diverse pragmatic sociomaterial context situations and settings of use (Bertelsen, 1998; 2000; Star, 2010; Nicolini, Mengis and Swan, 2012). Table 7.6 provides a template outlining and describing nature qualities categorised in five groups (with examples): *a blurry nature*; *a transitional and dynamic nature*; *a shifting status and role nature*; *a fallible yet good enough nature*; and *an evolutionary nature*. Appendix L.4 provides more detailed descriptions and example explanations relevant to the mHealth physical activity behaviour change intervention app context. Examples correspond to the example icons in Figure 7.8.

*Table Appendix L.4: Nature Qualities of Boundary Objects [Source: Researcher's own construction, informed by boundary object theory (Chapter 5, Section 5.3.2), critical theoretical analysis findings (Chapter 6, Section 6.5.6), Star and Griesemer (1989), Bowker and Star (1999), Carlile (2004), Engeström and Blackler (2005), Carlile (2006), Star (2010), Nicolini, Mengis and Swan (2012), Carlile, et al. (2013), Stoytcheva (2015), and Huvila, et al. (2017)]*

| Nature Quality | Sub-Nature Qualities and Description | Examples |
|---|---|---|
| **Blurriness** | A boundary object can simultaneously inhabit more than one category and type depending on the pragmatic manner in which interdisciplinary collaborating team members employ and use the object in particular contexts and actionised situational settings. | *Creative materials* such as paper, canvases, pens, colour pencils, glue, sticky notes, paints and paint brushes that inhabit the *"Tertiary General Boundary Objects"* and *"Other Supporting Artefacts and Materials"* non-design category types can fall into the *"Tertiary Design Boundary Objects"* category type when employed by interdisciplinary team members for specific design purposes in design situations and settings (Figure 7.8).<br><br>*Methods* such as those intended for agile software app development and alpha or beta testing that inhabit the *"Supporting Methods"* category type can also fall into the *"Secondary Design Boundary Objects"* category type when adapted, altered and contextualised to suit an interdisciplinary team's project and design context (Figure 7.8). |

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| **Transitional and Dynamic** | **Category and type transitioning and dynamism**<br>A boundary object can transition (shift) from one category and type to another depending on the pragmatic manner in which interdisciplinary collaborating team members employ and use the object in particular contexts and actionised situational settings. | The *materials and artefacts constituting a mHealth physical activity behaviour change intervention app* may not form part of the *"Primary Design Boundary Objects"* category type until they are crystallised into the prototype form and sufficiently encapsulate the necessary informatic and work needs and enable cross-disciplinary translation (Figure 7.8). For instance, a range of materials and artefacts such as a mobile device, android operating system software, user interface design guidelines, app software code and BIT element workflows need to be incorporated and embedded in the mHealth intervention app to constitute a working app prototype. |
| | **Foreground and background transitioning**<br>A boundary object can transition (shift) from the background to the foreground (and vice versa) during different stages and activities of the mHealth intervention project and interdisciplinary collaborative process. Depending on the situational contexts and settings, and the actors' intentions, knowledge and experiences, boundary objects can be called into the foreground to be utilised for certain tasks. Once their roles and purposes have been fulfilled, and they are no longer useful for a given task at hand, these boundary objects will shift back into the background where they will remain until called upon again. | *Prototyping methods ("Supporting Methods"), CAD software ("Tertiary Design Boundary Objects") and design documentation ("Secondary Design Boundary Objects")* will be largely called upon by team members during Step 5 (Table 7.3) when creating low-, middle- and high-fidelity mHealth behaviour change intervention app prototype versions (Figure 7.8).<br><br>During Step 1 (Table 7.3) interdisciplinary team members will largely focus on developing *project and team documentation* (*"Secondary Design Boundary Objects"* and *"Secondary General Boundary Objects"* in Figure 7.8). At various stages of the mHealth intervention project's lifespan, interdisciplinary collaborating team members can call upon and refer to the documentation (and even revise/alter it) when necessary. For instance, refer to and/or revising the project scope (example in *"Secondary General Boundary Objects"* in Figure 7.8). |
| | **Knowledge capability transitioning and dynamism**<br>A boundary object can transition between, or inhabit more than one, knowledge boundary capability depending on sociomaterial constellation in which it is embedded and pragmatically utilised. | The *BIT Model*, *BIT-Tech Framework* and *BIT Workflow* (*"Primary General Boundary Objects"* in Figure 7.8) will encapsulate and embed syntactic, semantic and pragmatic knowledge. A mHealth physical activity behaviour change intervention app (*"Primary Design Boundary Objects"* in Figure 7.8) will encapsulate and embed syntactic, semantic and pragmatic design knowledge.<br><br>*Standardised forms and methods* utilised by the interdisciplinary collaborating team members (*"Secondary Design Boundary Objects"* and *"Secondary General Boundary Objects"* in Figure 7.8) will encapsulate and embed syntactic and semantic (design, development and evaluation) knowledge. |
| **Shifting Status and Role** | **Contextualised shifting status and role**<br>In relation to transitions and dynamism, the status and role of a boundary object can change depending on the sociomaterial constellation and context in which it is embedded and utilised. The role of a boundary object may shift if new informatic requirements and work (situational or task) processes are incorporated. The status and role of a boundary object may shift when employed for different purposes and tasks at different steps and activities of the interdisciplinary collaborative process. Also, a boundary object proven to be of high value and utility may hold a higher status within a mHealth intervention project, team and setting, depending on the activities and objectives. | The contextual status and role of an interdisciplinary collaborating *team's documentation* may change if new informatic requirements and work (situational or task) processes and activities are added (example in *"Secondary Design Boundary Objects"* in Figure 7.8).<br><br>The status positioning and value of a *working and fully functional mHealth physical activity behaviour change intervention app prototype* (example in *"Primary Design Boundary Objects"* in Figure 7.8) will gradually increase as the project progresses throughout its lifespan, and will hold considerable status when being iteratively refined, updating and evaluated in Steps 5, 6, 8 and 9 (Table 7.3). |

| | | |
|---|---|---|
| | **Actor-related shifting status and role**<br>The status and role of boundary objects can shift and change depending on the community (disciplinary) backgrounds, capabilities, experiences, knowledge, skills and expectations of the actors using them in practice. These actor-related shifts are entangled with contextual shifts. A specific boundary object may produce multiple and different affordances for different actors across different contexts; actors can interpret and use the same object differently. The status and role of a boundary object can also shift in response to new actors or new actor requirements. | The *output product (mHealth physical activity behaviour change intervention app)* produced using the exact same interdisciplinary collaborative process will differ depending on the team members' community (disciplinary) backgrounds, capabilities, experiences, knowledge, skills and expectations involved in its design, development and evaluation (example in *"Primary Design Boundary Objects"* in Figure 7.8).<br><br>The same *taxonomy*, such as the *CALO-RE* or *BCT v1* (example in *"Secondary General Boundary Objects"* in Figure 7.8), will produce multiple, different affordances and interpretations for different actors, depending on the team members'' different community (disciplinary) backgrounds, capabilities, experiences, knowledge, skills and expectations in relation to a mHealth intervention app project and design problem context. |
| | **Relational shifting status and role**<br>A boundary object can shift in its status and role in relation or in response to other boundary objects. | A *method* or *framework* (examples in *"Secondary General Boundary Objects"* in Figure 7.8) that has shown to be more effective and useful for serving specific practice purposes may replace another method or framework, causing the current method or framework to lose status relevance and role positioning, thereby shifting it into the background (new one shifts to the foreground). |
| **Fallible yet Good Enough** | All boundary objects are fallible and none of them can provide team members with "catch-all" absolute or perfect solutions (Nicolini, Mengis and Swan, 2012, p.8). "No boundary objects can be universally useful" (Stoytcheva, 2015, p.5), "should not aim to cover the whole wide spectrum of phenomena involved in cross-disciplinary collaboration" (Nicolini, Mengis and Swan, 2012, p.9) and none can offer "magic bullet" answers (Carlile, 2006, p.23). Boundary objects cannot be intricately whole or complete, do "not *need* to be accurate to be useful" (Star, 2010, p.608) and they can also "fail" (Huvila, et al., 2017, p.1812). Instead, boundary objects should aim to provide interdisciplinary collaborating teams with "vague" yet "good enough road map[s]" (Star and Griesemer, 1989, p.410). | The framework's proposed *interdisciplinary collaborative process* (framework main component 2, example in *"Secondary General Boundary Objects"* in Figure 7.8) (Section 7.4) does not provide a "catch-all" perfect solution to designing, developing and evaluating mHealth physical activity behaviour change intervention apps. It is not universally useful for all project, health behaviour and mobile app application contexts, and does not provide "magic bullet" answers. The interdisciplinary collaborative process is not complete or whole, and can fail in pragmatic use depending on the manner in which actors (teams) employ and use it in a given mHealth intervention app project's practice. However, the interdisciplinary collaborative process does provide a general comprehensive and valuable guideline, offering a "vague" yet "good enough road map" for interdisciplinary collaborating teams intending to design, develop and evaluate mHealth physical activity behaviour change intervention apps. |
| **Evolutionary** | Every boundary object follows a form of evolutionary life span (Engeström and Blackler, 2005) or a "career" (Nicolini, Mengis and Swan, 2012, p.41). They are "in a constant process of (re)making" (Huvila, et al., 2017, p.1812). The life trajectories of boundary objects are messy and iterative over time, and largely change in relation to the sociomaterial constellations in which they are employed and embedded. Any changes, additions and revisions affect the boundary objects' lifespans, and some experience "growth [and] development", while others become obsolete and experience "death and failure" (Star, 2010, p.613). | After numerous design-test/evaluate-refine cycle iterations, the first *MVP alpha version of a mHealth physical activity behaviour change intervention app* (Step 5 of the interdisciplinary collaborative process in Table 7.3) will change drastically by the time it becomes a successful beta release candidate version ready for public consumer app market deployment (Steps 7 and 8). Thereafter, through continuous testing, delivery and improvement updates, the post-market released mHealth physical activity behaviour change intervention consumer app will continue to change (Step 9), until the team decides to stop updating and fixing the consumer app, leading to its ultimate death and failure. |

# Appendix M.1 (Chapter 7): Additional Boundary Object (Knowledge Artefact) Examples

## 7.6.4 The Role of Boundary Objects (Knowledge Artefacts) in Knowledge: Additional Boundary Object (Knowledge Artefact) Examples

***Boundary Objects (Knowledge Artefacts) at the Knowledge Boundaries and in Shared Understanding***

At the *syntactic knowledge boundary* (bottom blue bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Syntactic boundary objects need to be able to sufficiently transfer knowledge, process information and provide interdisciplinary collaborating team members with a common (shared) language to communicate, exchange, assess and share knowledge across heterogeneous practice community boundaries. A magnification into the blue syntactic circle in Figure 7.10 provides examples of syntactic boundary objects (corresponding to *"boundary objects"*, Figure 7.8) including a common glossary and the CALO-RE and BCT v1 coding taxonomies. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional syntactic boundary objects (knowledge artefact) examples.

Based on the findings from the critical theoretical analysis (Chapter 6), syntactic boundary objects also include: a standardised language (*lingua franca*); common glossaries (of terminologies and concepts); the unified DHI taxonomy; the TBCM development taxonomy; the PSDM principles; the Behavioural Theories Toolbox; and the Toolkit of Behavioural Strategies. Other syntactic knowledge artefacts include: shared repositories; shared storage databases; shared CAD databases; shared classification systems; shared library and filing systems; common lexicons; shared matrices; and shared ontologies (Star and Griesemer, 1989; Carlile, 2002; 2004; Eriksson, 2008; Rosenkranz, Vranešić and Holten, 2014; Melville-Richards, 2015; Uusitalo, 2015; Koskela, et al., 2016; Kanwal, et al., 2019). Essentially, considering that interdisciplinary collaborating team members "come from different fields" and "often speak different languages", the creation and utilisation of shared syntactic objects should provide common consensus (agreed-upon) language and dialects that help "bridg[e] the

language gap[s] … between the different fields involved in the [mHealth intervention app design and] development process" (Blanson Henkemans, et al., 2015, p.54-55; Approach #19).

At the *semantic knowledge boundary* (middle yellow bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing and learning about knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Semantic boundary objects need to be able to sufficiently translate knowledge, make interpretations of meaning explicit (that is, help make tacit knowledge explicit) and provide interdisciplinary collaborating team members with common (shared) meanings to communicate, deliberate, assess and share knowledge across heterogeneous practice community boundaries. A magnification into the yellow semantic circle in Figure 7.10 provides examples of semantic boundary objects (corresponding to *"boundary objects"*, Figure 7.8) including: the BCW; standardised shared templates; standardised shared forms; standardised shared checklists; the mERA Checklist; the CALO-RE and BCT v1 taxonomies; and the Dyadic Lenses. In addition, shared (common) processes, and more specifically, the framework's proposed *"interdisciplinary collaborative process"* (second main component, Figure 7.2) functions at the semantic knowledge boundary. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional semantic boundary objects (knowledge artefact) examples.

Based on the findings from the critical theoretical analysis (Chapter 6), semantic boundary objects include: shared methods, frameworks and models; standardised shared patterns; shared co-visions; shared (consensus) co-understandings; co-design, co-development, co-deployment and co-evaluation processes and methods; shared strategy plans; shared collaborative methods; and "entire cooperative frameworks" (Scandurra, Hägglund and Koch, 2008a, p.560; Approach #16) that outline informatics requirements and work processes, arrangements, routines and practices. Additional semantic knowledge artefacts include the standardised WHO's (2010b; 2002c) *Guideline Recommendations for Physical Activity for Health*, the British Standards Institution *Code of Practice for Health and Wellbeing Apps (PAS 277:2015)*, accessibility standards (for example, WCAG 2.0, W3C/WAI), standardised Android and Apple app developer policies, and quality, privacy and security standards. Other semantic knowledge artefacts include: standardised visual design principles; shared guidelines; common methodologies; standardised drawing formats and rules; standardised modelling notations; ethical protocols, procedures and policies; legislative regulations; and standardised reporting standards (such as CONSORT-EHEALTH) (Star and Griesemer, 1989; Carlile, 2002; 2004;

Eriksson, 2008; Abraham, 2015; Melville-Richards, 2015; Uusitalo, 2015; Koskela, et al., 2016; Kanwal, et al., 2019).

The findings from the critical theoretical analysis (Chapter 6) also reveal differences in meaning interpretations for commonly used terminology, including: “usability”; “acceptance” (or “acceptability”); “adherence”; “user experience”; “engagement”; “persuasiveness” (or “persuadability”); “satisfaction”; “enjoyment” (or “enjoyable”); “motivation” (or “motivating”); and “convincing”. These differences in interpretation of meaning between the interdisciplinary collaborating team members need to be addressed and overcome through the development and use of semantic boundary objects (knowledge artefacts). Failure to differentiate between interpretations of meaning can “lead to misunderstandings” (Blanson Henkemans, et al., 2015, p.54; Approach #19) that can hinder interdisciplinary team members’ communication, coordination, cooperation and collaboration efforts, and if not managed accordingly, can negatively affect the design, development and evaluation of mHealth (physical activity) behaviour change intervention consumer app products. In essence, given the differences and dependencies in knowledge, expertise, skill and activity contributions offered by heterogeneous interdisciplinary team members, semantic boundary objects are necessary for supporting the creation of common (shared) meanings, which in turn enables and facilitates knowledge translation across boundaries of collaborating practice communities.

At the *pragmatic knowledge boundary* (top green bidirectional arrow, Figure 7.10), boundary objects (knowledge artefacts) are characterised as representing, learning about and transforming knowledge (Carlile, 2002; Dirckinck-Holmfeld, 2006). Pragmatic boundary objects need to be able to sufficiently transform knowledge, generate “creative abrasions” and provide interdisciplinary collaborating team members with common (shared) interests to communicate, negotiate, assess and share political knowledge across heterogeneous practice community boundaries (Carlile, 2004, p.559; Uusitalo, 2015, p.43). A magnification into the green pragmatic circle in Figure 7.10 provides examples of pragmatic boundary objects (corresponding to *“boundary objects”*, Figure 7.8). Examples are: mHealth (physical activity) behaviour change intervention app prototypes, ranging from low- to high-fidelity, including manual and/or digital user interface design app screen mock-ups, sketches, storyboards, flow diagrams, wireframes, basic functional and interactive MVP apps, alpha app prototype versions, beta app prototype versions, 2D and 3D app prototyping simulations, and the final released mHealth (physical activity) behaviour change intervention consumer app. In addition,

all interdisciplinary team and project documentation developed (and revised) throughout the interdisciplinary collaborative process (Table 7.1 and Table 7.3) will function at the pragmatic knowledge boundary because these documents inherently incorporate political negotiations, trade-offs and decision-making with regard to team members' different (and often conflicting) values and interests. Two pragmatic boundary object examples included in Figure 7.10 (green circle) are the shared interdisciplinary team document and the shared design vision solution document on the instantiated conceptual and technological mHealth intervention app design. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional pragmatic boundary objects (knowledge artefact) examples.

Based on the findings from the critical theoretical analysis (Chapter 6), pragmatic boundary objects also include: design scenarios; mHealth stories; design rationale; use case scenarios, diagrams and narratives; common concept maps; end user personas; requirements and claims specification cards; and communal (shared) pictures and diagrams. Other pragmatic knowledge artefacts include: logic modelling and flow diagrams (such as the Logic Model of Change); shared negotiation plans and processes; shared conflict resolution plans and processes; boundary work activity maps; and interdisciplinary collaborative work process and practice maps (Carlile, 2002; 2004; Eriksson, 2008; Abraham, 2015; Melville-Richards, 2015).

For the most part, pragmatic boundary objects provide interdisciplinary collaborating team members with concrete and tangible knowledge artefacts that can be used to enable, support, facilitate and mediate communications and negotiations around different (and often conflicting) values, interests and goals regarding a given mHealth behaviour change intervention app's design, development and testing/evaluation. Pragmatic knowledge artefacts in the form of primary design boundary objects are valuable for engaging interdisciplinary collaborating team members in perspective-making and perspective-taking practices, motivating them to establish shared understanding(s), and drive and trigger innovative thinking and the joint collaborative generation (co-creation) of new transformative knowledge and mHealth (physical activity) behaviour change intervention app design solutions.

At the *shared understanding* base (purple rectangle in Figure 7.10), boundary objects (knowledge artefacts) are *co-created* and *co-produced* by interdisciplinary collaborating team members during the interdisciplinary collaborative process (Table 7.1 and Table 7.3) to support, facilitate and mediate the development and maintenance of shared mental models and common understandings (Mengis, 2007; Kosonen, 2015; Melville-Richards, 2015; Uusitalo,

2015; Stange, 2017; Kanwal, et al., 2019). Shared understandings need be able to provide interdisciplinary collaborating team members with common ground to productively engage in knowledge sharing (transfer, translation and transformation), knowledge integration and knowledge generation (creation) practices and processes. Shared understanding co-created and co-produced boundary objects (knowledge artefacts) correspond to the nine steps of the interdisciplinary collaborative process (framework main component 2, Table 7.1 and Table 7.3). A magnification into the purple shared understanding circle in Figure 7.10 provides examples of co-created boundary objects (corresponding to *"boundary objects"*, Figure 7.8) which generally include co-produced project, team, process and product documentation. Based on the critical theoretical analysis findings (Chapter 6), Appendix M.1 provides additional shared understanding co-created boundary object (knowledge artefact) examples.

At Step 1, shared understanding co-created boundary objects (knowledge artefacts) include: a co-developed common knowledge base; a co-developed shared interdisciplinary collaborative process plan; shared interdisciplinary team documentation (such as contracts; Filip, 2016); shared project documentation (such as a project proposal; Filip, 2016); shared business plan and business model documentation (for example, Makela, 2015); and shared informatic and work outlines for team communication, coordination, cooperation and collaboration.

At Step 2, shared understanding co-created boundary objects (knowledge artefacts) largely concern a common co-definition document outlining and detailing the interdisciplinary team's shared understanding of the problem space (in terms of health behaviour, target behaviour, target population, digital (mobile app) technology and context).

At Step 3.1, shared understanding co-created boundary objects (knowledge artefacts) include: co-created change objective matrices for the health (promotion) behaviour change intervention; co-created change objective matrices for user interaction; a co-created shared Logic Model of Change; a co-developed mHealth intervention app value map; an early collaborative co-creation of mHealth stories; and a shared co-developed theoretical base solution document for the mHealth (physical activity) behaviour change intervention app.

At Step 3.2, shared understanding co-created boundary objects (knowledge artefacts) include: co-created common behavioural science summary sheets; co-produced guiding principles; revised co-created mHealth stories; a co-developed high-level mHealth intervention app components (techniques and practical strategies), sequence and user flow; and a co-produced

shared vision (common solution) document (outlining the theoretical and conceptual base solution).

At Step 4, shared understanding co-created boundary objects (knowledge artefacts) include: co-created motivational frames; revised co-created mHealth stories; a co-created BIT-Tech framework and diagram; co-created complex (translation and operationalisation) instantiation matrices; a co-created Final mHealth Intervention App Logic Model; co-designed and co-produced low-fidelity conceptual instantiation mHealth intervention app design solution(s); and refined guiding principles. In addition, Step 4 includes: co-produced detailed mHealth intervention app design instantiation components (techniques, practical strategies, app design features), sequence, user flow(s) and workflows; a co-developed and co-produced shared design vision (common design solution) document (outlining and detailing the conceptual and technological mHealth (physical activity) behaviour change intervention app design solution); and a co-developed preliminary alpha testing prototyping plan.

At Step 5, shared understanding co-created boundary objects (knowledge artefacts) include: a revised co-produced alpha app prototyping plan; co-refined mHealth stories; co-developed and co-produced shared MVP and alpha app prototyping documentation; a co-designed and co-developed MVP (near-fully functional) alpha mHealth (physical activity) behaviour change intervention app (app prototype); and a co-developed preliminary pilot and beta testing plan.

At Step 6.1, shared understanding co-created boundary objects (knowledge artefacts) include: a revised co-produced pilot testing plan; co-developed shared pilot testing documentation; and a co-developed and co-refined fully functional alpha mHealth (physical activity) behaviour change intervention app (app prototype).

At Step 6.2, shared understanding co-created boundary objects (knowledge artefacts) include: a revised co-produced beta testing plan; co-developed shared beta testing documentation; and a co-developed and co-refined mHealth (physical activity) behaviour change intervention app as a beta release candidate.

At Step 7, shared understanding co-created boundary objects (knowledge artefacts) include: a co-produced mHealth app deployment plan; revised co-developed business plan, model and documentation; and a collaboratively co-produced shared deployment plan and documentation.

At Step 8, shared understanding co-created boundary objects (knowledge artefacts) include: a co-produced a summative evaluation plan (for both mHealth app user engagement and intervention efficacy and effectiveness over a period of time); shared co-developed and co-produced summative evaluation documentation; and a co-produced updated and improved mHealth (physical activity) behaviour change intervention consumer market app based on summative evaluation findings.

At Step 9, shared understanding co-created boundary objects (knowledge artefacts) include: co-produced post-market surveillance and continuous improvement strategies and plans for the mHealth (physical activity) app's remaining commercial market (app store) lifecycle; co-produced additional post-market strategies and plans (relating to business, monetisation and marketing); co-produced shared post-market documentation (for the remainder of the app's lifespan; for example, data analytics, bug fixes and app updates); and co-produced project reports.

# Appendix M.2 (Chapter 7): Guideline Recommendations for Applying Knowledge

### 7.6.5.1 Knowledge: Application: Guideline Recommendations for Applying Knowledge

Knowledge is a fundamental and indispensable contributor to the success of any given mHealth (physical activity) behaviour change intervention app project (Uusitalo, 2015) and is deeply ingrained and interwoven with the other three main and two supplementary framework components. The key challenge with knowledge, however, is that it is "localised, embedded and invested in practice" (Carlile, 2002, p.442), is often tacit in nature, lying implicitly in the minds of interdisciplinary collaborating team members (Kosonen, 2015), and is not always consciously and adequately considered and managed effectively, leading to hindrances and obstructions (Carlile, 2004; Tell, et al., 2017). For interdisciplinary teams to effectively communicate, coordinate, cooperate, collaborate, negotiate and achieve the mHealth intervention app project goals and objectives, and effectively overcome knowledge boundaries and develop shared understandings, interdisciplinary team members need to deliberately and consciously make their "sticky" tacit knowledge explicit (Tell, et al., 2017, p.48). Employing and using shared standardised templates (such as Appendix J.2) and shared guidelines (such as Appendix J.3 and Appendix M.2) can support interdisciplinary collaborating team members' knowledge elicitation and explication process. Instead of proposing strict and rigid prescriptive guidelines for applying knowledge, optional guidelines recommendations are offered (Appendix M.2). There are three optional guideline recommendations, pertaining to: (1) *understanding the importance and role of knowledge*; (2) *understanding knowledge management*; and (3) *using standardised templates and shared guidelines*.

***Guideline 1: Understanding the Importance and Role of Knowledge***

Knowledge is a fundamental and indispensable contributor to the success of any given mHealth (physical activity) behaviour change intervention app project and is deeply ingrained and interwoven with the other three main and two supplementary framework components. In other words, knowledge is deeply rooted in the mHealth intervention app project as a whole, in all nine steps of the interdisciplinary collaborative process, in the boundary objects and supporting

artefacts, and in the mHealth (physical activity) behaviour change intervention app consumer product. Importantly, the mHealth consumer app cannot be designed and produced without diverse knowledge contributions from all relevant interdisciplinary team members (stemming from heterogeneous communities of practice), which through the process of designing, developing and evaluating the app, knowledge gradually becomes ingrained and crystallised in the final material product output. Therefore, the mHealth intervention app project outcomes cannot be achieved without diverse and constant knowledge contributions.

From a pragmatic perspective, knowledge is "localised, embedded and invested in practice" (Carlile, 2002, p.442) and performs an enduring reciprocative bidirectional flow between influencing actors' enacted steps and activities, and both influences and is informed by actors' pragmatic sociomaterial actions in the real world. More simply put, knowledge informs practice and practice informs knowledge; the two are interdependent. Knowledge is therefore deeply embedded in all of the interdisciplinary collaborative process steps, activities and tasks.

Knowledge is also deeply ingrained within boundary objects and supporting artefacts, and is "localised around particular objects… and [is] invested in given outcome[s]" (Carlile, 2004, p.7). One of the core properties of boundary objects (knowledge artefacts) is that they sufficiently capture the informatic requirements (or needs) and work practices, processes and arrangements of the interdisciplinary collaborating team members using them. This information architecture and structure of boundary objects essentially means that they are intrinsic holders, facilitators and mediators of knowledge sharing and shared understanding across heterogeneous practice community boundaries. When communicating, cooperating, collaborating and negotiating around (and through) boundary objects, interdisciplinary collaborating team members are able to represent, learn about and transform knowledge together. In terms of boundary object characteristics and nature qualities, knowledge also plays an essential role in the contextualisation, malleability, utility, stability and evolutionary lifespan management and constant re-construction of boundary objects over time.

Furthermore, when interdisciplinary team members collaborate to develop new co-created and co-produced boundary objects (knowledge artefacts), they essentially go through a joint process of embedding and configuring knowledge within the new shared artefacts. Moreover, boundary objects (knowledge artefacts) and supporting artefacts also inform and structure the type and degree of knowledge that actors' acquire and possess over time. In short, boundary objects and supporting artefacts (1) encapsulate and carry knowledge (embedded inside their

core structure), (2) inform team members' practices, and (3) team members' practices inform their (new) production and (ongoing) revision and re-construction.

***Guideline 2: Understanding Knowledge Management***

Knowledge is a fluid, flexible, dynamic, evolutionary and multidimensional concept that is heavily contingent on actors and the contexts and situational settings in which they operate and practice. Recommendations for application propose that interdisciplinary collaborating teams be made aware and cognisant of knowledge as a concept and its importance, and be sufficiently informed about the three progressively complex knowledge boundaries, knowledge processes and communication processes that operate at syntactic, semantic and pragmatic levels across heterogeneous practice communities. Along with this awareness, they should understand the three knowledge boundary aims that need to be achieved in order to address and overcome knowledge challenges and the introduction of new circumstances at each boundary. This process requires actors to gain an understanding of the characteristics of knowledge boundaries in terms of complexity, knowledge properties (differences, dependencies and novelties) and actors' stakes and trade-offs, as well as the ascending scale that transitions from low complexity (where circumstances are generally known) to high complexity (where circumstances are generally unknown).

In addition, interdisciplinary collaborating team members need to grasp the importance of developing common ground and shared understanding, and recognise it as the base foundation upon which all knowledge sharing and interdisciplinary collaborative process steps, activities and practices are carried out. Moreover, interdisciplinary collaborating teams should be cognisant of the integral role boundary objects (knowledge artefacts) play in representing, learning about and transforming knowledge at the boundaries, and understand boundary objects as key holders, facilitators and mediators for sharing and assessing knowledge across multiple heterogeneous practice communities. General interdisciplinary team members (boundary spanners/workers) should further be aware of the roles, reign positioning, responsibilities and political power negotiating and decision-making influence that chief and secondary knowledge brokers carry in mHealth intervention app projects.

Knowledge brokers' chief role concerns the managing of knowledge within a given mHealth intervention app project and interdisciplinary collaborating team. Knowledge brokers serve as "bridgemakers" (Filip, 2016, p.85) and "human bridges" (Ganter, 2011, p.7) for knowledge

sharing, shared understanding and boundary spanning/crossing activities, and are central "intermediaries" for ensuring that interdisciplinary team members effectively apply and engage in knowledge transfer, translation and transformation practices across heterogeneous practice community boundaries (Filip, 2016, p.85). Knowledge brokers are therefore indispensable to the success of a mHealth intervention app project and mHealth (physical activity) behaviour change intervention app consumer product.

***Guideline 3: Using Shared Standardised Templates and Shared Guidelines***

The key challenge with knowledge is that it is "localised, embedded and invested in practice" (Carlile, 2002, p.442) and is often tacit in nature, lying implicitly in the minds of interdisciplinary collaborating team members. Yet, when explicitly articulated between interdisciplinary collaborating team members, knowledge functions as an enabler and driver for ongoing communications, discussions and negotiations. For interdisciplinary teams to effectively communicate, coordinate, cooperate, collaborate, negotiate and achieve the mHealth intervention app project goals and objectives, and effectively overcome knowledge boundaries and develop shared understandings, interdisciplinary team members need to deliberately and consciously make their "sticky" tacit knowledge explicit (Tell, et al., 2017, p.48).

One way of eliciting tacit knowledge is by employing and using shared standardised templates, such as the shared *Interdisciplinary Collaborative Team Member and Perspectives Template* proposed in Subsection 7.3.2.1 (Appendix J.2), which requires team members to explicitly articulate their perspectives, contributions and willingness and commitment to engaging in dialogical interactions for knowledge sharing, knowledge integration, knowledge generation (creation) and shared understanding practices. Another way of eliciting tacit knowledge is by employing and using shared standardised guidelines, such as the *Guideline Recommendations for High-Performing Interdisciplinary Collaborative Teams* proposed in Subsection 7.3.2.1 (Appendix J.3), which recommends team members consistently engage in perspective-making, perspective-taking and mentalisation practices to help make implicit knowledge explicit, and to improve the collaborative performance of the team as a whole.

Using boundary objects such as Appendix J.2 and J.3 to articulate and externalise different perspectives and knowledge contributions within an interdisciplinary collaborating team aids the creation of common ground and shared understandings amongst heterogeneous team

members, fosters the generation (creation) of new knowledge, and supports the integration and transformation of knowledge to push beyond existing boundaries and produce innovative mHealth (physical activity) behaviour change intervention app product solutions.

# Appendix N (Chapter 8): Ethical Approval

## 8.8 Ethical Considerations: Ethical Approval

Conducting the virtual semi-structured interview empirical study requires adherence to several ethical considerations. In research, ethics are standards of behaviour and moral principles that guide a researcher's conduct and aim to protect the rights of persons participating in a study (Saunders, Lewis and Thornhill, 2016). Adhering to ethical principles and practices is imperative in DSR and information systems studies (Myers and Venable, 2014). During the empirical study, all communication and interaction with participants is conducted with respect, honesty, integrity, transparency and trust (Bhattacherjee, 2012). Ethical issues concerning privacy, confidentiality, anonymity, informed consent and non-maleficence are taken into account (Saunders, Lewis and Thornhill, 2016). The ethical considerations of this empirical study are elaborated on below:

- **Ethical approval:** Prior to the commencement of the empirical study, research ethical approval is obtained at departmental and institutional levels, from the Rhodes University Information Systems Department ethics committee and the Rhodes University Human Ethics Committee (RU-HEC), respectively. Ethical approval involves completing and submitting an online structured human ethics application through the Rhodes University Ethical Review Application System (ERAS). The official ethical approval letter is provided in Appendix N.

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**Rhodes University Human Ethics Committee**
PO Box 94, Makhanda, 6140, South Africa
t: +27 (0) 46 603 7727
f: +27 (0) 46 603 8822
e: s.manqele@ru.ac.za
**NHREC Registration number: RC-241114-045**

https://www.ru.ac.za/researchgateway/ethics/

14/12/2020

Callie Thomson

Email: g10T3512@campus.ru.ac.za

Review Reference: 2020-2774-4813

Dear Prof Caroline Khene

**Title:** A Framework for Guiding and Supporting the Multi-Disciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change

Principal Investigator: Prof Caroline Khene

Collaborators: Ms. Callie Thomson,

This letter confirms that the above research proposal has been reviewed and **APPROVED** by the Rhodes University Human Ethics Committee (RU-HEC). Your Approval number is: 2020-2774-4813

Approval has been granted for 1 year. An annual progress report will be required in order to renew approval for an additional period. You will receive an email notifying when the annual report is due.

Please ensure that the ethical standards committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloging number allocated.

Sincerely,



**Prof Arthur Webb**

**Chair: Rhodes University Human Ethics Committee, RU-HEC**

cc: Mr. Siyanda Manqele - Ethics Coordinator

# Appendix O (Chapter 8): Informed Consent Form

## 8.8 Ethical Considerations: Informed Consent Form

Conducting the virtual semi-structured interview empirical study requires adherence to several ethical considerations. In research, ethics are standards of behaviour and moral principles that guide a researcher's conduct and aim to protect the rights of persons participating in a study (Saunders, Lewis and Thornhill, 2016). Adhering to ethical principles and practices is imperative in DSR and information systems studies (Myers and Venable, 2014). During the empirical study, all communication and interaction with participants is conducted with respect, honesty, integrity, transparency and trust (Bhattacherjee, 2012). Ethical issues concerning privacy, confidentiality, anonymity, informed consent and non-maleficence are taken into account (Saunders, Lewis and Thornhill, 2016). The ethical considerations of this empirical study are elaborated on below:

- **Informed consent:** The principle of informed consent involves the researcher disclosing sufficient information about the study, which allows potential participants to reach a fully informed, considered and autonomous decision about whether or not to participate in the interview process (Myers and Venable, 2014; Saunders, Lewis and Thornhill, 2016). Before the interview session, written informed consent is obtained by providing respondents with a consent form to sign (manually or digitally) and return via email. Informed consent, for both the interview and recording, is confirmed at the start of each virtual interview (verbal informed consent). The informed consent form outlines the purpose of the study, acknowledges the rights of participants and notes the potential uses of the study findings. The informed consent form details participants' rights: the right to voluntary participation; the right to withdraw at any point in time; the right to ask questions and seek clarity on any subject they are asked about; the right to privacy, confidentiality and anonymity; and any anticipated benefits of the research. The consent form is provided in Appendix O.

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**PARTICIPANT INFORMED CONSENT**

# INFORMED CONSENT DECLARATION

**(Participant)**

**Project Title: A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change**

**Callie Thomson** from the **Department of Information Systems**, Rhodes University, has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration is provided to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to gain insight into and understanding of the actors, boundary objects, supporting artefacts, processual activities and knowledge sharing practices relevant to the design, development and evaluation of mHealth intervention applications (apps) for physical activity behaviour change.

2. The Rhodes University has given ethical clearance to this research project and I may request to see the clearance certificate by contacting Mr Siyanda Manqele (s.manqele@ru.ac.za) (Ref # 2020-2774-4813).

3. By participating in this research project I will be contributing towards an improved contextual understanding of the design, development and evaluation of physical activity mHealth behaviour change intervention apps, which will benefit researchers and practitioners, and add value to the growing body of knowledge in the multi- and interdisciplinary digital health intervention development area.

4. I will participate in the project by partaking in a once off virtual semi-structured interview, scheduled at a date and time agreed upon by myself and the researcher. The interview will be conducted using teleconferencing technology (e.g. Zoom). Based on my knowledge, skills and experience, the interview requests that I answer several questions pertaining to the actors/persons, objects/artefacts, processual activities and knowledge sharing practices relevant to the design, development and evaluation of physical activity mHealth behaviour change intervention apps.

5. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

6. I will not be compensated for participating in the research.

7. The risks associated with my participation in this study are low considering that the semi-structured interview questions are of a work-related nature based on my professional experience and expertise. The questions will not require that I share my personal belief or value systems, nor will they request that I share my intimate personal lived experiences (e.g. family, relationships, traumatic events, et cetera).

8. The Principal Investigator intends publishing the research results in the form of academic journal articles and a doctoral dissertation. Confidentiality and anonymity of records will strictly be maintained. My name, identity and organisation/institution of work will not be revealed to anyone who has not been involved in the conducting of the research.

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9. I understand that I will not receive feedback regarding the results and findings obtained from the study, unless specifically requested from the Principal Investigator.

10. I agree to the Principal Investigator's request to video, voice and audio record me as a participant for the duration of the virtual semi-structured interview. I am aware that the audiovisual recording data will be collected using teleconferencing software, and will be downloaded and saved to the Principle Investigator's personal computer after the interview is complete.

11. I agree to the Principal Investigator's use of video, voice and audio recording of my answers, comments and opinions during the virtual semi-structured interview.

12. Any further questions that I might have concerning the research, or my participation will be answered by the Principle Investigator, Callie Thomson, who can be contacted via email: g10t3512@campus.ru.ac.za.

13. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

14. An electronic copy of this informed consent declaration will be provided to me, and the original will be kept on record.

I, ……., have read the above information and can confirm that the above information has been provided to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

…….  …….
**Participants signature**  **Date**

Rhodes University, Research Office, Ethics
Ethics Coordinator: ethics-commitee@ru.ac.za
t: +27 (0) 46 603 7727 f: +27 (0) 86 616 7707
Room 220, Main Admin Building, Drostdy Road, Makhanda (Grahamstown), 6139

# Appendix P (Chapter 8): Interview Guide

## 8.10 Conclusion: Interview Guide

*Table 8.9: Summary of Methodological Design Guiding the Empirical Evaluation Study [Source: Researcher's own construction]*

| Research Methodology Component | Research Methodology Decision |
|---|---|
| **Research Approach** | • Qualitative Design Science Research (DSR) linguistic interpretivist approach |
| **Research Strategy** | • Interview survey strategy |
| **Data Collection Design** | • Qualitative interviews<br>• Initial planned interview timeframe: Monday, 11 January 2021 to Friday, 22 January 2021<br>• Actual interview timeframe: Friday, 22 January 2021 to Friday, 12 February 2021, with the exception of one postponed interview on Wednesday, 24 February 2021 |
| **Empirical Study Research Question** | • What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context? |
| **Empirical Study Research Objective** | • To evaluate, revise and enhance the quality of the Interdisciplinary mHealth App Design Framework by exploring and investigating its components and subcomponents in the context of the mHealth physical activity (promotion) behaviour change intervention app application domain environment |
| **Unit of Analysis** | • The actor, boundary object and supporting artefact, knowledge sharing and process (and activity) content relevant to the mHealth physical activity behaviour change intervention consumer app context |
| **Research Instrument** | • Virtual semi-structured interviews<br>• Interview guide (Appendix P)<br>• Virtual platform: Zoom Video Communications Inc. |
| **Sampling Technique** | • Purposive snowball sampling<br>• The snowball rolled four times through chain referrals |
| **Sample Recruitment Process** | • 40 prospective participants (in academia and industry) were contacted directly via email using a standardised template (Appendix Q), with attachments including a formal signed "Invitation Letter" (Appendix R) and a formal "Information Sheet" (Appendix S). This started the snowballing process<br>• Willing participants signed the form "Participant Consent Form" (Appendix O)<br>• 110 prospective participants (inclusive of academia and industry) were invited<br>• 31 voluntarily willing participants took part in the study (final sample size) |

| | |
|---|---|
| **Data Analysis Design** | • Thematic analysis, incorporating a hybrid deductive and inductive cognitive reasoning strategy<br>• NVivo QSR International |
| **Data Validation** | • Prolonged engagement with data<br>• Audit trails<br>• Reflexive journaling<br>• Memoing<br>• Coding frameworks<br>• Diagramming<br>• Thick descriptions<br>• Transparent reporting<br>• Data person and source triangulation |
| **Ethical Considerations** | • Ethical approval<br>• Informed consent<br>• Privacy, confidentiality and anonymity<br>• Relationship building<br>• Honesty and accuracy<br>• Non-maleficence and risk management<br>• Beneficence |

# Researcher Interview Guide

## Project Title: A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change

**Participant Personal Details**

- First Name:*
- Last Name:*
- Gender:
- Age:
- Degree/Qualifications:
- Occupation:
- Organisation/Institution:*

**Personal information is solely captured for data collection purposes. Personal information will remain strictly confidential and will be coded when transcribed.*

**Qualitative Virtual Semi-Structured Interview Introduction**

- Length: 45-60 minutes
- Primary goal: To gain insight into and understanding of the actors, boundary objects, supporting artefacts, processual activities and knowledge sharing practices relevant to the design, development and evaluation of mHealth intervention apps for physical activity behaviour change.

**Participant Inclusion Criteria**

- Knowledge, skills and experience in the process of designing, developing and evaluating physical activity mHealth behaviour change intervention apps.
- Experience as a team member on multi-/interdisciplinary physical activity mHealth behaviour change intervention app projects.
- Knowledge, skills and experience can pertain to academia, research and/or industry.

**Consent**

- Written consent – obtained prior to virtual interview.
- Verbal consent – obtained at the start of virtual interview.

**Introductory Questions**

- What are your areas of specialisation?
  - *Prompt for Discipline behind specialisation (e.g. Information Systems, Health Psychology, Health Behavioural Sciences, Computer Sciences)*
- For how long have you been involved in work on physical activity mHealth behaviour change intervention apps?
- How many physical activity mHealth behaviour change intervention app projects have you been involved in?
  - *Range: 1 – 3 projects; 4 – 7 projects; 7 – 10 projects; 10+ projects.*
- What roles/positions have you held in these projects?
  - *E.g. Team Leader; Project Manager; Empirical Study Facilitator; General Team Member.*
- Can you name any published physical activity apps you have been involved with?
  - *App type: Consumer or Research? E.g. MyFitnessPal; 5K Runner; Runtastic; HelpMeDot!; Puzzle Walk.*
- Can you describe the scale and scope of physical activity mHealth behaviour change intervention app projects in general?
  - *E.g. Local (Community level); National; International; 1-Month; 6-Month; 12-Month; 1+ Year.*
- Can you describe the typical outcomes and objectives of physical activity mHealth behaviour change intervention app projects?

| Actors Content Questions | Prompt For | BO View TFW Examples** |
|---|---|---|
| • What are the different disciplines and areas of specialisation relevant to the design, development and evaluation of physical activity mHealth behaviour change intervention apps? | • Discipline and area specialisation titles | • Information Systems<br>• Health Psychology |

| | | |
|---|---|---|
| • What are the different team members' roles in a project team? | • Role/position titles | • HBCI Designer<br>• Physical activity expert<br>• Exercise Scientist |
| • Who generally leads the project? | • Role/position title(s) | • Project Manager<br>• Team Leader |
| • Can you identify any third party stakeholders generally involved in projects? | • Third party stakeholder titles | • Physical Activity Expert Consultant<br>• Personal Trainer<br>• HBCI Researcher |
| • Can you describe whether end users are involved in projects? If so, how? | • Direct/indirect involvement | • Participatory EUs<br>• EU Testing |
| **Interdisciplinary Process Content Questions** | **Prompt For** | **BO View TFW Examples**** |
| • Can you describe the general process steps and activities carried out in producing physical activity mHealth behaviour change intervention apps? | • Process name<br>• Name/title of each process step<br>• Name/title of each activity<br>• Clear descriptions of each step<br>• Clear descriptions of each activity<br>• From conception/initiation to release | (1) Project and Team Formalisation<br>(2) Problem Understanding<br>(3) Theoretical and Conceptual Base Solution Development<br>(4) Instantiated Conceptual and Technological Solution Design<br>(5) Instantiated Concrete Solution Design and Development<br>(6) Formative Evaluation<br>(7) Deployment<br>(8) Summative Evaluation<br>(9) Post-Market Release Surveillance and Continuous Improvement |
| • Can you describe the typical nature of the design, development and evaluation process? | • Clarify descriptions | • Interdisciplinary<br>• Collaborative<br>• Structure (systematic; non-linear)<br>• Agile (iterative; cyclical; feedback looping; continuous; flexible; adaptable; reflective; reflexive)<br>• Quality (theory-based; evidence-based) |
| **Boundary Objects Content Questions** | **Prompt For** | **BO View TFW Examples**** |
| • What objects do you commonly utilise for project and team management?<br>• What objects are commonly utilised when designing the physical activity app?<br>• What objects are commonly utilised when developing the physical activity app?<br>• What objects are commonly utilised when evaluating the physical activity app? | • Clear examples of Primary BOs<br>• Central artefacts of collaborative focus and heteropraxial activities<br>• Meets three main BO criteria | • Team, project and business documentation<br>• Prototypes (low-, medium-, high-fidelity)<br>• Sketches, diagrams, mock-ups, wireframes<br>• BIT-Tech diagrams, user flow, UI screens |
| • What methods are commonly utilised to facilitate and support the interdisciplinary team through the collaborative design, development and evaluation process? | • Clear examples of Secondary BOs<br>• Communication, cooperation, coordination, collaboration<br>• Collective work praxes/modes of action<br>• Meets three main BO criteria | • Processes, methods, shared work procedures<br>• Standardised forms, templates<br>• BCW, BCTT, MS<br>• Shared glossaries<br>• Shared taxonomies, checklists, toolkits |
| • What infrastructure objects and materials are commonly utilised to indirectly support and sustain the team's collaboration and the design, development and evaluation process? | • Clear examples of Tertiary BOs<br>• Sociomaterial infrastructure<br>• Meets three main BO criteria | • Technology, CAD software, digital prototyping devices, PP, communication systems, teleconferencing, creative materials |
| **Supporting Artefacts Content Questions** | **Prompt For** | **BO View TFW Examples**** |

| | | |
|---|---|---|
| • What supporting methods are commonly employed, referred to or adapted during the design, development and evaluation process? | • Clear examples of Supporting Methods<br>• Borrowed; does not meet BO criteria | • CI/CD, alpha/beta testing, DevOps, JITAIs, Android app development process, data analytics process, RCT process |
| • What supporting guidelines, standards and codes of practices are commonly utilised during the design, development and evaluation process? | • Clear examples of Supporting Guidelines, Standards and Codes of Practice<br>• Borrowed; does not meet BO criteria | • WHO PA guidelines, other PA/exercise guidelines, app store standards and policies, HI guidelines, quality criteria, codes of practice |
| • What other supporting artefacts, materials, frameworks and models are generally employed or referred to during the design, development and evaluation process? | • Clear examples of Other Supporting Artefacts<br>• Borrowed; does not meet BO criteria | • Existing apps, PA FW, business canvas, publications, reports, literature, Precede-Proceed FW |
| **Knowledge and Knowledge Boundary Content Questions** | **Prompt For** | **BO View TFW Examples**** |
| • Considering that team members generally come from different disciplinary backgrounds and hold different kinds of specialist knowledge and experience, how does a mutli-disciplinary collaborative team generally negotiate and overcome differences in knowledge and perspectives?<br>o *Clarifier: Different perspectives in terms of problem and solution space* | • Identify objects and artefacts used<br>• Communications, negotiations<br>• Trade-offs, power stakes | • Knowledge sharing practices and processes<br>• Overcoming knowledge boundaries |
| • Can you explain how a team generally fosters shared understanding amongst team members? | • Objects and artefacts that aid SU<br>• SMMs; common ground | • Co-creation, co-design, co-development, co-evaluation, co-production |
| • How does a team generally overcome differences in language, terminology and vocabulary? | • Syntactic KB<br>• Common language; transfer; exchange | • Glossaries, taxonomies, syntaxes, lexicons, BCTT, shared DB, filing and classification system |
| • Can you describe how a team generally overcomes differences in interpretations?<br>o *Clarifier: Interpretations of problems, solutions. Meaning-making. Sense-making.* | • Semantic KB<br>• Common meanings; translate; deliberate | • MERA checklist, BCW, BCTT, dyadic lenses, shared checklists, shared processes/methods |
| • Can you describe how a team generally overcomes conflicts of interest?<br>o *Clarifier: Different interests, goals and/or objectives* | • Pragmatic KB<br>• Common interests; transform; negotiate<br>• Common goals, values, political interests | • Alpha, beta and MVP prototypes, sketches, storyboards, wireframes, screen designs, user flows, diagrams<br>• Shared team, project, business, design vision and development documentation |
| • Who is generally responsible for facilitating the development of shared understanding and common ground amongst team members? | • Role/position title(s) | • Knowledge broker |
| • As a team, how is knowledge generally created and integrated? | • Integration and generation of new knowledge | • Inter-disciplinary knowledge transformation |
| **Closing Questions** | | |
| • Do you have any suggestions or recommendations on how you would advise the design, development and evaluation process be improved for interdisciplinary teams and collaborative physical activity mHealth behaviour change intervention app projects in general? | | |
| **Concluding the Interview** | | |
| • Are there any further comments you would like to provide or questions you would like to ask?<br>• Would you like to be informed of the study findings once the data has been analysed?<br><br>• Thank the participant for their time.<br>• Reassure participant confidentiality, anonymity and privacy.<br>• Ask whether participant is comfortable to be contacted at a later date for any follow-up questions. | | |

**BO View TFW Examples** –** Examples for the Interviewer only. Examples provide Interviewer with key reminders of what information is intended to be investigated/sought after through the interview process.

# Appendix Q (Chapter 8): Standardised Email Template

## 8.10 Conclusion: Standardised Email Template

*Table 8.9: Summary of Methodological Design Guiding the Empirical Evaluation Study [Source: Researcher's own construction]*

| Research Methodology Component | Research Methodology Decision |
|---|---|
| **Research Approach** | • Qualitative Design Science Research (DSR) linguistic interpretivist approach |
| **Research Strategy** | • Interview survey strategy |
| **Data Collection Design** | • Qualitative interviews<br>• Initial planned interview timeframe: Monday, 11 January 2021 to Friday, 22 January 2021<br>• Actual interview timeframe: Friday, 22 January 2021 to Friday, 12 February 2021, with the exception of one postponed interview on Wednesday, 24 February 2021 |
| **Empirical Study Research Question** | • What are the key actor, process, object and knowledge sharing elements for guiding and supporting interdisciplinary collaborative design, development and evaluation in the mHealth physical activity behaviour change intervention app context? |
| **Empirical Study Research Objective** | • To evaluate, revise and enhance the quality of the Interdisciplinary mHealth App Design Framework by exploring and investigating its components and subcomponents in the context of the mHealth physical activity (promotion) behaviour change intervention app application domain environment |
| **Unit of Analysis** | • The actor, boundary object and supporting artefact, knowledge sharing and process (and activity) content relevant to the mHealth physical activity behaviour change intervention consumer app context |
| **Research Instrument** | • Virtual semi-structured interviews<br>• Interview guide (Appendix P)<br>• Virtual platform: Zoom Video Communications Inc. |
| **Sampling Technique** | • Purposive snowball sampling<br>• The snowball rolled four times through chain referrals |
| **Sample Recruitment Process** | • 40 prospective participants (in academia and industry) were contacted directly via email using a standardised template (Appendix Q), with attachments including a formal signed "Invitation Letter" (Appendix R) and a formal "Information Sheet" (Appendix S). This started the snowballing process<br>• Willing participants signed the form "Participant Consent Form" (Appendix O)<br>• 110 prospective participants (inclusive of academia and industry) were invited<br>• 31 voluntarily willing participants took part in the study (final sample size) |

| | |
|---|---|
| **Data Analysis Design** | • Thematic analysis, incorporating a hybrid deductive and inductive cognitive reasoning strategy<br>• NVivo QSR International |
| **Data Validation** | • Prolonged engagement with data<br>• Audit trails<br>• Reflexive journaling<br>• Memoing<br>• Coding frameworks<br>• Diagramming<br>• Thick descriptions<br>• Transparent reporting<br>• Data person and source triangulation |
| **Ethical Considerations** | • Ethical approval<br>• Informed consent<br>• Privacy, confidentiality and anonymity<br>• Relationship building<br>• Honesty and accuracy<br>• Non-maleficence and risk management<br>• Beneficence |

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 06 January 2021 18:56
**To:** [redacted]
**Subject:** Invitation to participate in PhD research study

Dear *[Title First Name Surname]*

My name is Callie Thomson. I'm a PhD candidate at Rhodes University. I was referred to you by *[name of person who snowball referred them]*, who shared your email contact. I am conducting a study on the multi- and interdisciplinary process for designing mobile health intervention applications (apps) targeting physical activity behaviour change.

Given your knowledge, experience and expertise in *[key area of knowledge, skills and expertise]*, I am hoping you may be willing to participate in the study. Participation involves taking part in one 45-60 minute one-on-one virtual interview. Interviews will take place between Friday, 22 January 2021 and Friday, 12 February 2021. Your name and institution/organisation of work will be kept completely confidential and will remain anonymous.

Please find attached an invitation letter (signed by myself and my principal supervisor) and an information sheet which will provide more details on the study. Ethical approval has been formerly granted by Rhodes University's Human Ethics Research Committee.

Please reply to this email address informing me as to whether or not you would like to voluntarily participate in the study. If you are willing to participate, a consent form will be provided for completion, and a mutually agreed date and time can be scheduled for the virtual interview to take place. If you do not wish to participate, please provide referrals to persons whom you think may be willing and able to participate in the study. This will help me complete the study and will be sincerely appreciated.

Thank you kindly for your time and I hope you find this invitation request favourable.

Kind regards
**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects

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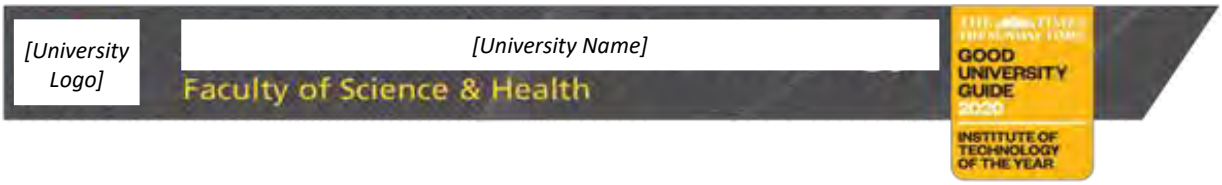
**From:** [redacted]
**Sent:** 03 February 2021 12:43
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Re: Invitation to participate in PhD research study

Hi Callie

An interesting project you have. I would be happy to participate. How can we move forward?

All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




**Dr** [redacted] **(she/her)**
Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

---

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 03 February 2021 16:29
**To:** [redacted].
**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*

Thank you kindly for your response and willingness to participate – sincerely appreciated.

Further details for scheduling the interview:

- Please find attached an informed consent form for signing and return via email. Manual signature not required; if easier, digital signature is welcome. Your personal name and your company of work will remain strictly 100% anonymous and confidential.
- May I please confirm your time zone? Is it perhaps CET, GMT+1?
- Will either dates Tuesday 9th, Wednesday 11th or Thursday 12th February 2021 suit you?

- Will an 1 hour slot between any times 12h00 and 17h00 (CET time zone?) on either of these dates suit your schedule?
    - If so, please feel welcome to select a date and time that suits you best.
    - If neither of these dates and times are suitable, please recommend a more preferred date and timeslot.
- Will Zoom be a suitable platform for you for holding the virtual interview?

My study uses a snowball sampling technique, which means it relies heavily on chain referrals. So I would be incredibly grateful if you can perhaps offer referrals of any other persons whom you think may be suitable to partake the study. I would really appreciate it. Thank you.

Kind regards

**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects



**From:** [redacted]
**Sent:** 04 February 2021 10:31
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Re: Invitation to participate in PhD research study

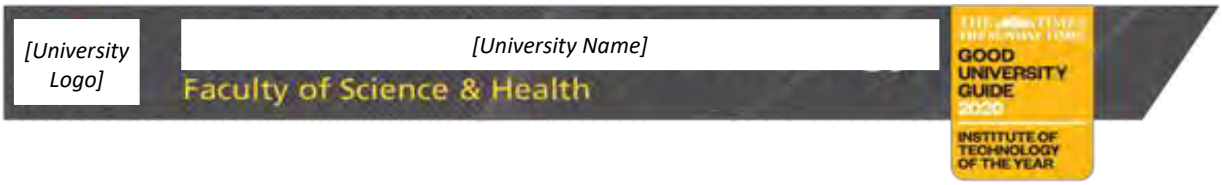
Hi Callie

Yes, my time zone is CET. Yes, Zoom works perfectly for me. Thursday, 11 Feb at 2pm works best for me. Looking forward to meeting with you.

As for referrals, I can suggest the following people:
- [redacted] *[Full Name – Email Address]*
- [redacted] *[Full Name – Email Address]*

Please find my signed consent form attached.
All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




**Dr** [redacted] **(she/her)**
Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

---

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 04 February 2021 14:05
**To:** [redacted]
**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*

Please find below Zoom link for the rescheduled remainder of interview – for 11th Feb from 14h00-15h00 CET.
Please find snapshot below of details in case.

# Interview for Research Study - PC21

[redacted]

Meeting ID: [redacted]

Start | Copy Invitation | Edit | Delete

Hide Meeting Invitation

Callie Thomson is inviting you to a scheduled Zoom meeting.

Topic: Interview for Research Study - PC21
Time: [redacted]

Join Zoom Meeting
[redacted]

Meeting ID: [redacted]
Passcode: [redacted]

Kind regards

**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects

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---

**From:** [redacted]
**Sent:** 04 February 2021 20:38
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Accepted: Interview for Research Study – PC21

[redacted]

[redacted]

**Accepted: Interview for Research Study – PC21**

When [redacted]
Location [redacted]

[redacted] has accepted this meeting.

---

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Hi *[Prospective Participant First Name]*
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Chat tomorrow.

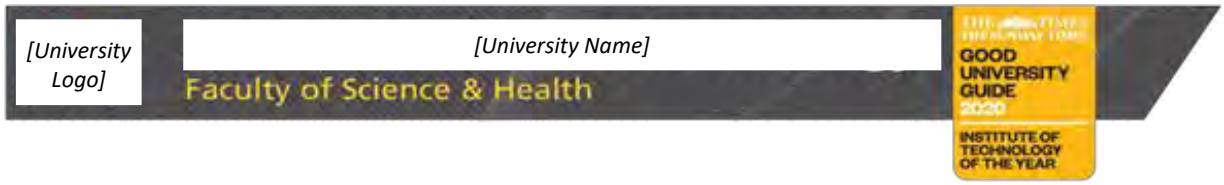
Kind regards
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**From:** [redacted]
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**Subject:** Re: Invitation to participate in PhD research study

Hi Callie
Thanks for the reminder. Speak then.
All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




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Professor in Health Psychology
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[redacted] *[Office and University Address]*

# Appendix R (Chapter 8): Invitation Letter

## 8.10 Conclusion: Invitation Letter

*Table 8.9: Summary of Methodological Design Guiding the Empirical Evaluation Study [Source: Researcher's own construction]*

| Research Methodology Component | Research Methodology Decision |
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Given your knowledge, experience and expertise in *[key area of knowledge, skills and expertise]*, I am hoping you may be willing to participate in the study. Participation involves taking part in one 45-60 minute one-on-one virtual interview. Interviews will take place between Friday, 22 January 2021 and Friday, 12 February 2021. Your name and institution/organisation of work will be kept completely confidential and will remain anonymous.

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Thank you kindly for your time and I hope you find this invitation request favourable.

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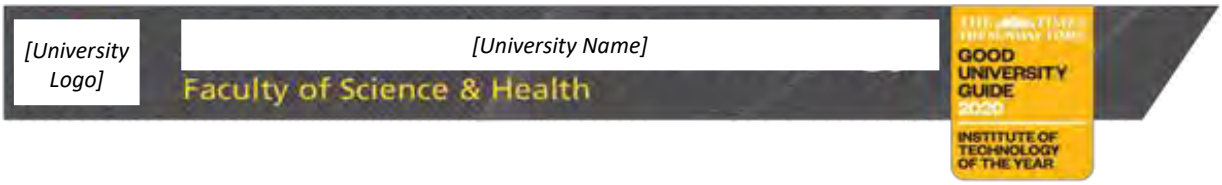
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All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




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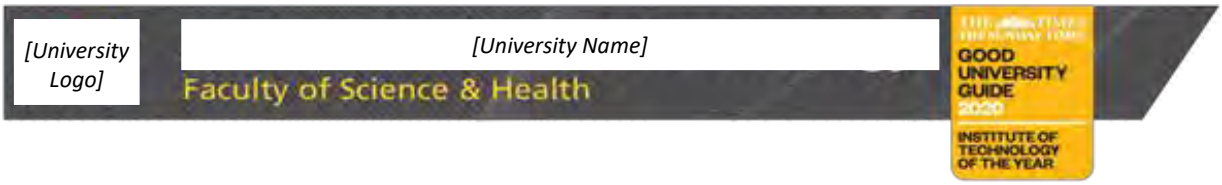
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All the best,
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Hi *[Prospective Participant First Name]*

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Please find snapshot below of details in case.

# Interview for Research Study - PC21

[redacted]

Meeting ID: [redacted]

Start | Copy Invitation | Edit | Delete

Hide Meeting Invitation

Callie Thomson is inviting you to a scheduled Zoom meeting.

Topic: Interview for Research Study - PC21
Time: [redacted]

Join Zoom Meeting
[redacted]

Meeting ID: [redacted]
Passcode: [redacted]

Kind regards

**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects

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---

**From:** [redacted]
**Sent:** 04 February 2021 20:38
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Accepted: Interview for Research Study – PC21

[redacted]

[redacted]

**Accepted: Interview for Research Study – PC21**

When [redacted]
Location [redacted]

[redacted] has accepted this meeting.

---

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 10 February 2021 09:15
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**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*
This email serves as a gentle reminder about the interview tomorrow, Thursday, 11th February 2021 from 14h00-15h00 (GMT+1).
Thanks again for your time and willingness. Really appreciate it.
Chat tomorrow.

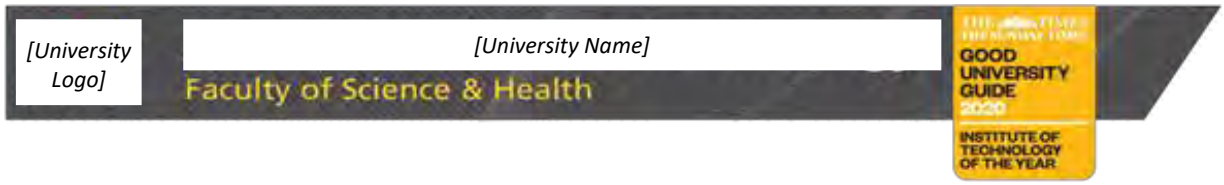
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Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

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**Department Of Information Systems**
**Rhodes University**
**Grahamstown Makhanda**
**6140**
**South Africa**
**Tel: [+27] 046 603 8244**
**E-mail: g10t3512@campus.ru.ac.za**

Date: *[Date Invitation Letter Sent]*

Dear *[Title Prospective Participant Full Name]*

**Invitation to Participate in a Research Study Virtual Semi-Structured Interview**

I, Callie Thomson, under the supervision of Professor Caroline Khene as a registered full-time doctoral student at Rhodes University, am conducting a research study entitled "A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change". The aim of this research is to develop a framework to guide and support the design, development and evaluation of physical activity mHealth behaviour change intervention application (app) projects. Your participation and contribution to this project is important and valuable for enriching and accurately portraying the contextual relevance of this proposed framework.

The one-on-one virtual semi-structured interview you are invited to participate in forms part of an empirical study, which seeks to gain insight into and understand the (1) multi-/interdisciplinary team actors, (2) process steps and activities, (3) boundary objects and supporting artefacts, and (4) knowledge boundary sharing practices applicable to the design, development and evaluation of mHealth intervention apps for physical activity behaviour change. The interview questions will require you to draw on your tacit and explicit knowledge, expertise, skills and experience as a professional having actively collaborated and contributed as a team member on one or more multi-/interdisciplinary physical activity mHealth behaviour change intervention app projects.

Please find attached an information sheet that provides further details on the study and what will be expected of you as a participant. The interview will require approximately 45 to 60 minutes of your time to complete, using videoconferencing software (such as Zoom) to conduct and record the interview. The interview process is planned to be conducted over the period **Friday, 22 January 2021 to Friday, 12 February 2021**. This study has been approved by Rhodes University's Department of Information Systems Ethics Committee and Rhodes University's Human Ethics Research Committee, and is in line with Rhodes University's Ethical Standards Protocol (Ref # 2020-2774-4813).

Thank you for your time and I hope to you find this invitation request favourable. For further questions please contact the researcher Callie Thomson directly via email at g10t3512@campus.ru.ac.za.

Yours sincerely,



**Callie Thomson**
*PhD Candidate (Researcher)*



**Professor Caroline Khene**
*Principal Supervisor*

# Appendix S (Chapter 8): Information Sheet

## 8.10 Conclusion: Information Sheet

*Table 8.9: Summary of Methodological Design Guiding the Empirical Evaluation Study [Source: Researcher's own construction]*

| Research Methodology Component | Research Methodology Decision |
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| **Research Instrument** | • Virtual semi-structured interviews<br>• Interview guide (Appendix P)<br>• Virtual platform: Zoom Video Communications Inc. |
| **Sampling Technique** | • Purposive snowball sampling<br>• The snowball rolled four times through chain referrals |
| **Sample Recruitment Process** | • 40 prospective participants (in academia and industry) were contacted directly via email using a standardised template (Appendix Q), with attachments including a formal signed "Invitation Letter" (Appendix R) and a formal "Information Sheet" (Appendix S). This started the snowballing process<br>• Willing participants signed the form "Participant Consent Form" (Appendix O)<br>• 110 prospective participants (inclusive of academia and industry) were invited<br>• 31 voluntarily willing participants took part in the study (final sample size) |

| | |
|---|---|
| **Data Analysis Design** | • Thematic analysis, incorporating a hybrid deductive and inductive cognitive reasoning strategy<br>• NVivo QSR International |
| **Data Validation** | • Prolonged engagement with data<br>• Audit trails<br>• Reflexive journaling<br>• Memoing<br>• Coding frameworks<br>• Diagramming<br>• Thick descriptions<br>• Transparent reporting<br>• Data person and source triangulation |
| **Ethical Considerations** | • Ethical approval<br>• Informed consent<br>• Privacy, confidentiality and anonymity<br>• Relationship building<br>• Honesty and accuracy<br>• Non-maleficence and risk management<br>• Beneficence |

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 06 January 2021 18:56
**To:** [redacted]
**Subject:** Invitation to participate in PhD research study

Dear *[Title First Name Surname]*

My name is Callie Thomson. I'm a PhD candidate at Rhodes University. I was referred to you by *[name of person who snowball referred them]*, who shared your email contact. I am conducting a study on the multi- and interdisciplinary process for designing mobile health intervention applications (apps) targeting physical activity behaviour change.

Given your knowledge, experience and expertise in *[key area of knowledge, skills and expertise]*, I am hoping you may be willing to participate in the study. Participation involves taking part in one 45-60 minute one-on-one virtual interview. Interviews will take place between Friday, 22 January 2021 and Friday, 12 February 2021. Your name and institution/organisation of work will be kept completely confidential and will remain anonymous.

Please find attached an invitation letter (signed by myself and my principal supervisor) and an information sheet which will provide more details on the study. Ethical approval has been formerly granted by Rhodes University's Human Ethics Research Committee.

Please reply to this email address informing me as to whether or not you would like to voluntarily participate in the study. If you are willing to participate, a consent form will be provided for completion, and a mutually agreed date and time can be scheduled for the virtual interview to take place. If you do not wish to participate, please provide referrals to persons whom you think may be willing and able to participate in the study. This will help me complete the study and will be sincerely appreciated.

Thank you kindly for your time and I hope you find this invitation request favourable.

Kind regards
**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects

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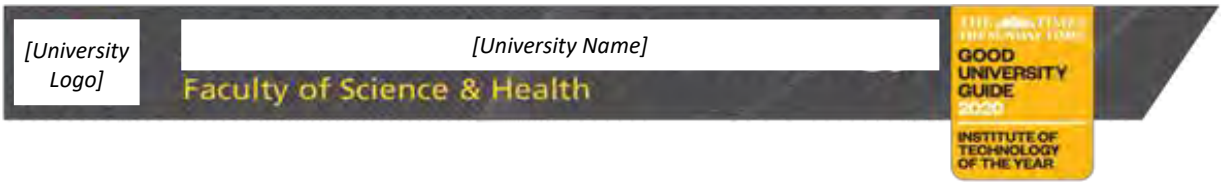
**From:** [redacted]
**Sent:** 03 February 2021 12:43
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Re: Invitation to participate in PhD research study

Hi Callie

An interesting project you have. I would be happy to participate. How can we move forward?

All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




**Dr** [redacted] **(she/her)**
Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

---

**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 03 February 2021 16:29
**To:** [redacted].
**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*

Thank you kindly for your response and willingness to participate – sincerely appreciated.

Further details for scheduling the interview:

- Please find attached an informed consent form for signing and return via email. Manual signature not required; if easier, digital signature is welcome. Your personal name and your company of work will remain strictly 100% anonymous and confidential.
- May I please confirm your time zone? Is it perhaps CET, GMT+1?
- Will either dates Tuesday 9th, Wednesday 11th or Thursday 12th February 2021 suit you?

- Will an 1 hour slot between any times 12h00 and 17h00 (CET time zone?) on either of these dates suit your schedule?
    - If so, please feel welcome to select a date and time that suits you best.
    - If neither of these dates and times are suitable, please recommend a more preferred date and timeslot.
- Will Zoom be a suitable platform for you for holding the virtual interview?

My study uses a snowball sampling technique, which means it relies heavily on chain referrals. So I would be incredibly grateful if you can perhaps offer referrals of any other persons whom you think may be suitable to partake the study. I would really appreciate it. Thank you.

Kind regards

**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects



**From:** [redacted]
**Sent:** 04 February 2021 10:31
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Re: Invitation to participate in PhD research study

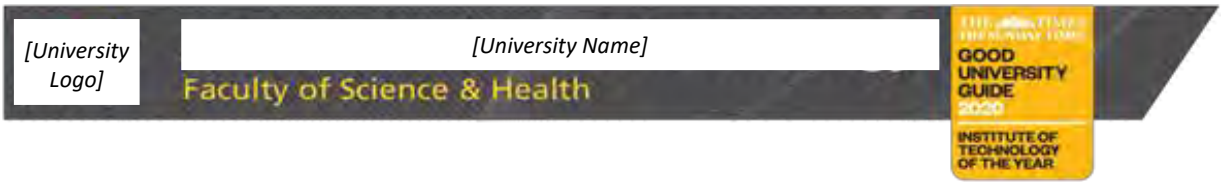
Hi Callie

Yes, my time zone is CET. Yes, Zoom works perfectly for me. Thursday, 11 Feb at 2pm works best for me. Looking forward to meeting with you.

As for referrals, I can suggest the following people:
- [redacted] *[Full Name – Email Address]*
- [redacted] *[Full Name – Email Address]*

Please find my signed consent form attached.
All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




**Dr** [redacted] **(she/her)**
Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

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**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 04 February 2021 14:05
**To:** [redacted]
**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*

Please find below Zoom link for the rescheduled remainder of interview – for 11th Feb from 14h00-15h00 CET.
Please find snapshot below of details in case.

# Interview for Research Study - PC21

[redacted]

Meeting ID: [redacted]

Start | Copy Invitation | Edit | Delete

Hide Meeting Invitation

Callie Thomson is inviting you to a scheduled Zoom meeting.

Topic: Interview for Research Study - PC21
Time: [redacted]

Join Zoom Meeting
[redacted]

Meeting ID: [redacted]
Passcode: [redacted]

Kind regards

**Callie Thomson**

***PhD Candidate in Information Systems***

Educational Technology Graduate Assistant for Economics
Contract Lecturer for Information Systems
Teaching Assistant for Information Systems Development Projects

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---

**From:** [redacted]
**Sent:** 04 February 2021 20:38
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Accepted: Interview for Research Study – PC21

[redacted]

[redacted]

**Accepted: Interview for Research Study – PC21**

When [redacted]
Location [redacted]

[redacted] has accepted this meeting.

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**From:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Sent:** 10 February 2021 09:15
**To:** [redacted]
**Subject:** Re: Invitation to participate in PhD research study

Hi *[Prospective Participant First Name]*
This email serves as a gentle reminder about the interview tomorrow, Thursday, 11th February 2021 from 14h00-15h00 (GMT+1).
Thanks again for your time and willingness. Really appreciate it.
Chat tomorrow.

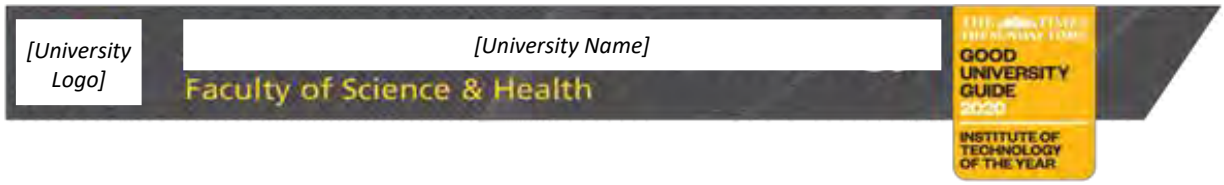
Kind regards
**Callie Thomson**
*[Shortened signature when appropriate]*




**From:** [redacted]
**Sent:** 10 February 2021 18:58
**To:** Callie Thomson <g10t3512@campus.ru.ac.za>
**Subject:** Re: Invitation to participate in PhD research study

Hi Callie
Thanks for the reminder. Speak then.
All the best,
*[First Name of Participant – Participants always used their first names]*

*[Participant Signature]*




**Dr** [redacted] **(she/her)**
Professor in Health Psychology
Digital Health Centre Director
**Phone**: [redacted]
**Email**: [redacted]




[redacted] *[Office and University Address]*

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**A Framework for Guiding the Interdisciplinary Design of mHealth Intervention Apps for Physical Activity Behaviour Change**

**Information Sheet**

*Please take some time to read this information and ask questions if anything is unclear.*
*Contact details can be found at the end of this document.*

**What is the purpose of the study?**

The study adopts a one-on-one virtual semi-structured interview structure that aims to develop and propose a framework to guide and support multi- and interdisciplinary project teams during the design, development and evaluation of mHealth intervention applications (apps) for physical activity behaviour change. It focuses on the collaboration efforts, process steps and activities, objects/artefacts and knowledge sharing practices of these teams.

The study aims to gain insight into and understanding of:

- The multi- and interdisciplinary team actors/persons involved in physical activity mHealth behaviour change intervention app projects.
- The design, development and evaluation process steps and activities pertaining to the production of physical activity mHealth behaviour change intervention apps.
- The boundary objects and supporting artefacts that team members generally employ, utilise and create to facilitate and mediate their multi- and interdisciplinary efforts and heteropraxial activities.
- The knowledge boundary sharing practices generally carried out by multi-disciplinary teams during the design, development and evaluation of physical activity mHealth behaviour change intervention apps.

**Who is organising the research?**

The research is developed and conducted by Ms Callie Thomson, a registered full-time doctoral student at Rhodes University, Makhanda (Grahamstown), South Africa. The doctoral project and virtual semi-structured interview study is overseen by Professor Caroline Khene as Principal Supervisor. The interview study instrument and questions have no potential harm to participants and has been reviewed and approved by Rhodes University's Department of Information Systems Ethics Committee and Rhodes University's Human Ethics Research Committee, and is in line with Rhodes University's Ethical Standards Protocol. The official ethical approval reference number is 2020-2774-4813.

**What are the possible benefits of participating?**

The study will provide insight into the multi- and interdisciplinary collaborating teams, process steps and activities, boundary objects and supporting artefacts, and knowledge sharing practices relevant to the design, development and evaluation of mHealth intervention apps targeting physical activity behaviour change in individuals. The results and findings of the study will be used to evaluate, refine and contextualise a preliminary conceptual framework which has already been developed by the researcher based on a critical in-depth theoretical and literature analysis. Participants are welcome to request the researcher share the analysed findings of the study when completed.

**Why have I been chosen?**

The study aims to conduct 25 to 30 virtual semi-structured interviews with participants who possess

knowledge, expertise, skills and sufficient experience as team members of multi- and interdisciplinary physical activity mHealth behaviour change intervention app projects. A minimum of two years constitutes sufficient experience. Project involvement may be research and/or commercial in nature, and may be past or current. Experience may be academic, research and/or industry based. Participants may be from or practice in several relevant disciplinary backgrounds, namely: Information Systems; Health Psychology; Health Behavioural Sciences; Persuasive Technology and Persuasive Systems Design; Game Design and Development; Computer Sciences; DevOps; Mobile and Application Design and Development; Business Management; Business and Product Development; Exercise Sciences; Sport Sciences; Fitness/Personal Training; and Physical Activity.

**Taking part in the study**

Participation in this study is voluntary and you may ask any questions before agreeing to participate in the virtual interview. If you agree to participate, you will be asked to complete and sign a consent form which will be emailed to you by the researcher. However, at any time, you are free to withdraw from the study and if you choose to withdraw, you will not be asked to provide any reasons.

Participants will be accepted until the maximum number is reached (n = 32). If this number is exceeded, it will not be possible to partake in the interview process.

The study employs a snowball sampling technique. Participants will be asked to provide referrals, recommendations and contact details of potential future participants whom meet the inclusion criteria, and whom the researcher deems suitable for the study. Participants are welcome to transparently inform the referred persons about their personal recommendations. The researcher is not obliged to select and interview all persons referred and/or recommended by participants.

**What will happen if I take part in the study?**

If you agree and consent to partake in this study you will participate in a one-on-one semi-structured interview that will be carried out online with the researcher. The interviews will be held virtually using videoconferencing technology that is internationally accessible and does not require premium software purchase or licencing, such as Zoom. If you agree to participate in the study, a mutually agreed upon date and time will be set and you will be emailed with a weblink and instructions on how to join the scheduled interview meeting.

The virtual interview meetings will be recorded using the in-built complementary videoconferencing software recording functionality. Participants' consent to recording the interview will be requested before the researcher commences the interview questioning process.

**When will the interviews take place?**

The interviews are planned to take place over the period Friday, 22 January 2021 to Friday, 12 February 2021. Interviews will take place on working days (Monday to Friday). An interview date and time will be agreed upon between yourself and researcher. The researcher will schedule the virtual interview meeting and will share the weblink with you via email. If you are unable to meet on the scheduled date and time, you are welcome to contact the researcher and a postponed date and time can be set.

**How long is the interview expected to take?**

The one-on-one virtual semi-structured interview should require approximately 45 to 60 minutes of your time to complete, and will be conducted on a mutually agreed upon scheduled date and time.

**What kinds of questions will I be asked in the interview?**

The interview questions are designed by the researcher. The interview questions require participants to draw on their tacit and explicit knowledge, expertise, skills and experience as a professional having actively collaborated and contributed as a team member on one or more multi- and interdisciplinary physical activity mHealth behaviour change intervention app projects. This project experience may be academic, research and/or industry based. The interview questions have no potential to harm for participants.

If you agree and consent to partake in the study, the interview will start by asking for your personal details (e.g. full name, degree/qualification, occupation and organisation/institution of work). This will be followed by a few introductory questions to identify your area of specialisation and experience (academic, research and/or industry) with physical activity mHealth behaviour change intervention app projects and will ask you to name any physical activity apps you have produced and/or published. The subsequent main interview questions will ask you to provide knowledgeable insight, linguistic terminology and contextual understanding regarding the multi- and interdisciplinary actors/persons typically involved in physical activity mHealth behaviour change intervention app projects and the objects/artefacts and knowledge practices that generally constitute the project teams' collaborative design, development and evaluation process. The interview will conclude with a question regarding any suggestions or recommendations you may have for improving the design, development and evaluation of physical activity mHealth behaviour change intervention apps.

**May I withdraw from participation in the study?**

At any time before or during the scheduled virtual interview you may choose to withdraw. There will be no consequences for withdrawing from the study.

**How will the interview data be used?**

The recorded interview data be transcribed and analysed by the researcher. No professional or third party transcription services will be asked to transcribe the data. Participants' personal details and organisations/institutions of work will be kept strictly confidential and will be anonymised and codified by the researcher during the transcription process. No names of individuals or organisations/institutions will be in the transcriptions, academic publications or dissertation findings discussion chapter.

**What will happen to the results of the project?**

All of the information and data collected during the course of the study will be kept strictly confidential. Your personal details and the organisation/institution at which you work will be anonymised. You will not be identified in any academic publications or in the doctoral dissertation.

**What happens to the virtual interview data collected during the study?**

Upon completion of the one-on-one virtual semi-structured interview, the researcher will download and save the interview recording to their personal desktop computer. No other person has password access to the computer. A backup of the interview recording will be saved to the researcher's external hard drive as a backup in the event that data on the personal desktop is lost or becomes corrupt. The data will be transcribed by the researcher and will not be shared with any professional or third party transcription services. The Principal Supervisor, Professor Caroline Khene, may request access to the data recordings.

As mentioned above, you are free to withdraw from the study at any point in time. If you choose to withdraw, your interview recording will be deleted and will not be transcribed or analysed during the study.

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**What about use of the data in future research?**

The data collected in this study will not be used for any other future research and will solely be used for the purposes as stated. The anonymised transcriptions will be kept for five years after the publication of the study findings, in line with Rhodes University's Ethical Standards Protocol.

**Is the number of participants limited?**

The study is designed to include twenty-five to thirty (25-30) participants. The maximum threshold is thirty-two (32) participants. If this number is exceeded, it will not be possible to partake in the interview process.

**What should I do if I have any concerns or complaints?**

If you have any concerns about the study, please communicate with the researcher directly, who should acknowledge your concerns within ten (10) working days and give you an indication of how your concerns will be addressed. The researcher can be contacted via email at g10t3512@campus.ru.ac.za. If you remain unhappy and wish to make a formal complaint, please contact Professor Caroline Khene via email at caroline.khene@dmu.ac.uk.

# Appendix T (Chapter 9): Research Participants

## 9.2 Research Participants

The interview sample comprised 31 voluntarily willing and consenting participants. This sample size surpassed the preliminary planned estimation for 25 to 30 participants, but did not exceed the maximum threshold of 32 participants (detailed in Chapter 8, Subsection 8.4.4). Participants spanned ten countries, including Austria, New Zealand, Australia, Sweden, Finland, Ireland, Singapore, Scotland, Belgium and Portugal. Of these countries, Australia was the most highly represented. Despite the researcher's numerous efforts, no participants living in England, the United States of America, Canada and other European and African countries were willing to participate in the study. Prospective participants working in England declined participation, reporting busy academic calendars (examination period). The reasons for lack of responses and declined participation from persons in the United States of America and Canada is unknown. As for African countries and South Africa, there is a scarcity of leading researchers and industry practitioners/companies, particularly given the interdisciplinary contextual knowledge and experience required for participation in this interview study.

Table Appendix T provides a summary overview of the 31 participants' demographic and key information. All participants were coded with unique identifiers to ensure confidentiality and anonymity, using numerical Participant Codes "PC#'s.", for example PC1 to PC31. Table Appendix T summarises the following information for each participant: gender; age; city, country (geographical positioning); degree and/or qualification; occupational position; form of experience as either academic or industry (or both); duration of experience (in years); as well as past and current role involvement experience as members of multi- or interdisciplinary mHealth physical activity behaviour change intervention app project teams. Participants' ages ranged 26 to 66 years, and there were 18 females and 13 males. Participants' duration of experience in the field spanned 2 to 23 years. Nine participants were solely academic/research focused, only three were exclusive industry practitioners (further supporting the academic-industry divide), and nineteen hold experience in both academia and industry (albeit, notably, these nineteen participants primarily practice in academia and research projects, but have experience in collaborating with industry and/or commercial companies). All participants, with the exception of one, hold higher postgraduate tertiary education (university) degrees, generally

Masters and Doctoral qualifications. As for areas of knowledge, skills, expertise and experience, the participants represent a heterogeneous and diverse sample, including all of the key actor disciplines and relevant communities of practice identified in the proposed Interdisciplinary mHealth App Design Framework (represented by the participants' various degrees/qualifications and occupational positions).

*Table Appendix T: Participants Demographic and Key Information [Source: Researcher's own construction]*

| PC No. | Gender | Country | Degree/ Qualification | Occupational Position | Academia/ Industry | Years of Experience | Project Role Involvement |
|---|---|---|---|---|---|---|---|
| **PC1** | Female | Austria | • Communications and Graphic Design Certification | • Head of Product Design<br>• Head of UID/UXD (Past) | Industry | 4.5 Years | • Product Leader<br>• Team Manager<br>• Team Member |
| **PC2** | Female | New Zealand | • PhD (Community and Public Health)<br>• MBChB (Bachelor of Medicine and Bachelor of Surgery) | • Associate Professor<br>• Clinical Director at District Health Board | Academia and Industry | 17 Years | • Principal Investigator<br>• Co-Investigator<br>• Team Member |
| **PC3** | Male | Austria | • MBA (Master of Business Administration, Project Management)<br>• Technology Honours (Information Systems Analysis and Design) | • Principal Product Designer<br>• Senior UXD (Past)<br>• UXD (Past) | Industry | 2 Years | • Product Leader<br>• Project Manager<br>• Team Manager<br>• Team Member |
| **PC4** | Female | Australia | • Bachelors (Information Technology)<br>• LLB (Bachelor of Laws) | • Research Officer at Digital Health Centre<br>• Project Manager | Academia | 2 Years | • Project Manager<br>• Team Manager<br>• Team Member |
| **PC5** | Female | Australia | • PhD (Health Sciences)<br>• Bachelor of Medicine | • Senior Research Fellow (Digital Health, Health Behaviour Change) | Academia and Industry | 6 Years | • Chief Investigator<br>• Team Member |
| **PC6** | Female | Australia | • Masters (Information and Communications Technology) | • Full-Time PhD Candidate (Health Informatics and Artificial Intelligence) | Academia | 5 Years | • Research Student |
| **PC7** | Female | Australia | • PhD (Kinesiology, Sport and Exercise Psychology) | • Senior Lecturer (Health Behaviour Change, Physical Activity)<br>• Director (Motivation of Health Behaviours Lab) | Academia and Industry | 12 Years | • Project Planning<br>• Chief Investigator<br>• Team Member |
| **PC8** | Male | Australia | • Honours (Computer Science) | • Software Architect | Academia and Industry | 3.5 Years | • Lead Developer<br>• Team Member |
| **PC9** | Male | Australia | • PhD (Health, Physical Education and Fitness) | • Research Professor<br>• Chair (Physical Activity Society)<br>• Former Chair (e&mHealth Group, ISBNPA) | Academia and Industry | 9-10 Years | • Principal Investigator<br>• Co-Investigator<br>• Team Leader<br>• Project Leader<br>• Collaborator<br>• Team Member |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PC10** | Male | Australia | • PhD (Public Health)<br>• Honours (Human Movement Science) | • Research Professor (Public Health, Digital Health) | Academia and Industry | 10 Years | • Principal Investigator<br>• Co-Investigator<br>• Team Leader<br>• Project Leader<br>• Collaborator<br>• Team Member |
| **PC11** | Female | Australia | • PhD (Health; Aged, Chronic and Palliative Care)<br>• Honours (Nursing) | • Research Associate (Digital Health)<br>• Registered Nurse | Academia and Industry | 6 Years | • Project Manager<br>• Team Leader<br>• Team Member |
| **PC12** | Female | Australia | • PhD (Computer Science) | • Senior Lecturer (Health Informatics) | Academia and Industry | 6 Years | • Principal Investigator<br>• Project Manager<br>• Team Leader<br>• Team Member |
| **PC13** | Male | Australia | • PhD (Computer Science)<br>• MBBS (Bachelor of Medicine and Bachelor of Surgery)<br>• Masters (Biomedical Engineering)<br>• Diploma (Deployment Computer Studies) | • Senior Lecturer (Health Informatics)<br>• Medical Director (Past) | Academia and Industry | 21 Years | • Project Manager<br>• Team Manager<br>• Team Member |
| **PC14** | Female | Australia | • PhD (Health Sciences)<br>• Honours (Physiotherapy) | • Research Professor (Digital Health, Exercise, Nutrition and Physical Activity) | Academia and Industry | 16 Years | • Principal Investigator<br>• Project Manager<br>• Team Manager/ Leader |
| **PC15** | Female | Australia | • PhD (Public Health)<br>• Honours (Health Sciences) | • Research Associate (Digital Health) | Academia and Industry | 8 Years | • Team Member |
| **PC16** | Male | Australia | • PhD (Computer Science)<br>• Honours (Information Technology) | • Lecturer (Digital Health, Social Media, Computer Science) | Academia | 6 Years | • Team Member |
| **PC17** | Male | Sweden | • PhD (Clinical Neuroscience)<br>• Licenced Clinical Psychologist | • Researcher (Digital Health, Clinical Psychology, Substance Use Behaviour) | Academia | 8 Years | • Team Member |
| **PC18** | Male | Finland | • PhD (Medical Engineering Technology)<br>• Masters (Telecommunications Engineering)<br>• Bachelors (Business Information Systems) | • Postdoctoral Candidate (Digital Health, Health Behaviour Change) | Academia | 8 Years | • Team Member<br>• Research Student |
| **PC19** | Female | Australia | • Honours (Research Psychology) | • Full-Time PhD Candidate (Psychology and Digital Health) | Academia | 3 Years | • Research Student |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PC20** | Female | Finland | • PhD (Computing and Electrical Engineering)<br>• Masters (Signal and Image Processing) | • Senior Scientist (Digital Health, Smart Health) | Academia and Industry | 17 Years | • Project Manager<br>• Team Manager/ Leader<br>• Team Member |
| **PC21** | Female | Ireland | • PhD (Psychology and Health)<br>• Masters (Applied Positive Psychology)<br>• Licenced Health Psychologist | • Program Director (Applied Psychology)<br>• Lecturer (Applied Psychology, Digital Health) | Academia and Industry | 7 Years | • Team Manager/ Leader<br>• Team Member |
| **PC22** | Male | Australia | • PhD (Health Sciences)<br>• Honours (Sport and Exercise Science) | • Postdoctoral Research Fellow (Digital Health, Health Behaviour Change, Physical Activity) | Academia | 9 Years | • Team Member<br>• Research Student |
| **PC23** | Female | Belgium | • Masters (Physical Education and Movement Sciences) | • Full-Time PhD Candidate (Sport Science and Health Psychology) | Academia | 2.5 Years | • Research Student |
| **PC24** | Male | Finland | • PhD (Information Systems) | • Full Professor (Information Systems, Persuasive Technology) | Academia and Industry | 18 Years | • Principal Investigator<br>• Team Manager<br>• Collaborator<br>• Team Member |
| **PC25** | Female | Belgium | • PhD (Health Sciences and Psychology) | • Postdoctoral Researcher (Digital Health, Psychology) | Academia | 6 Years | • Research Student |
| **PC26** | Female | Australia and Tasmania | • PhD (Public Health)<br>• MBA (Master of Business Administration) | • Professor (Digital Health)<br>• Director (Digital Health) | Academia and Industry | 23 Years | • Principal Investigator<br>• Project Manager /Leader<br>• Project Officer<br>• Team Manager/ Leader |
| **PC27** | Male | Portugal | • PhD (Sport Sciences) | • Associate Professor (Digital Health, Physical Activity, Exercise, Obesity and Health Psychology)<br>• Executive Director (ISBNPA) | Academia and Industry | 20 Years | • Principal Investigator<br>• Project Co-Ordinator<br>• Project Manager<br>• Team Manager/ Leader<br>• Co-Investigator<br>• Collaborator<br>• Team Member |
| **PC28** | Female | Scotland and Singapore | • PhD (Exercise Physiology) | • Senior Scientist (Digital Health, Future Health Technology) | Academia and Industry | 8 Years | • Team Manager<br>• Team Member |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PC29** | Male | Austria | • Masters (Engineering, Mobile Computing) | • Head of Product (Product Management Lead) | Industry | 10 Years | • Product Leader<br>• Project Manager<br>• Team Manager<br>• Team Member |
| **PC30** | Female | Belgium | • PhD (Health Sciences)<br>• Masters (Clinical and Health Psychology)<br>• Masters (Marketing Analysis and Planning) | • Assistant Professor (Digital Health, Psychology) | Academia and Industry | 9 Years | • Principal Investigator<br>• Project Manager<br>• Team Leader<br>• Team Member |
| **PC31** | Male | Belgium | • PhD (Communication Sciences and Media Studies)<br>• Masters (Marketing Analysis)<br>• Masters (Statistical Data Analysis) | • Postdoctoral Research Fellow (Digital Health, Physical Activity) | Academia and Industry | 9 Years | • Project Manager<br>• Team Leader<br>• Team Member |