USER INTERFACE DESIGN GUIDELINES FOR DIGITAL TELEVISION VIRTUAL REMOTE CONTROLS

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by

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Declaration

I, Alicia Veronica Wentzel, declare that the dissertation entitled, "*User Interface Design Guidelines for Digital Television Virtual Remote Controls*", which I hereby submit for the degree, Master of Commerce at Rhodes University, is my own work. I also declare that this dissertation has not previously been submitted by me for a degree at this or any other tertiary institution and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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Alicia Veronica Wentzel

Abstract

The remote control is a pivotal component in households worldwide. It helps users enjoy leisurely television (TV) viewing. The remote control has various user interfaces that people interact with. For example, the physical user interface includes the shape of the remote and the physical buttons; the logical user interface refers to how the information is laid out; and the graphical user interface refers to the colours and aesthetic features of the remote control. All of the user interfaces together with the context of use, cultural factors, social factors, and prior experiences of the user influences the ways people interact with their remote control and ultimately has an effect on their user experiences.

Advances in the broadcasting sector and transformations of the TV physical remote control have compounded the simple remote control into a multifaceted, indispensable device, overcrowded with buttons. The usability and ultimately the user experience of physical remote controls (PRCs) have been affected by the overloaded functionality and small button sizes. The usability issues with current PRCs, the evolution of mobile phones into touchscreen smartphones, and the trend of global companies moving towards virtual remote controls (VRCs) have prompted this research to discover what user interface design features will contribute towards an enhanced user experience for digital TV VRCs.

This research used the design science research process model (DSRP), which comprised six steps, to investigate this topic area further. A review of the domain literature pertaining to mobile user experiences (MUX) and all the encompassing factors, mobile human computer interaction (MHCI) and the physical, logical, graphical and natural user interfaces was completed, as well as a review of the literature regarding the usability issues of PRCs and VRCs. A contextual task analysis (CTA) of a single South African digital TV PRC was used to identify how users utilise PRCs to perform tasks, and the usability issues they encountered during the tasks. Brainstorming focus groups were used to understand how to represent certain user interface elements and attempted to source ideas from users about what potential functionality digital TV VRCs should contain. Together with all the other results gathered from the previous chapters amalgamated into a set of user interface design guidelines for digital TV VRCs. The proposed user interface guidelines were used to instantiate a digital TV VRC prototype that underwent usability testing in order to validate the proposed user interface design guidelines. The results of the usability testing revealed that the user interface design guidelines for digital TV VRCs were successful, with the addition of one guideline that was discovered during the usability testing.

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Chapter 1 Introduction

This chapter introduces the research study and provides a background to the research by describing the research context, as well as the problem statement and motivation for the research. The research questions and sub-questions are defined and the research methodology utilised is described. The scope of the research is defined and the chapter concludes with an outline of the dissertation chapters.

1.1 Background

In home entertainment systems, television (TV) viewing has always been considered a leisurely activity, performed alone or for social reasons. The TV has become one of the most common entertainment devices in most homes (Wang, Chung & Yan, 2009). A study performed in China showed that TV viewing and playing on the computer were the most prevalent screen time behaviours among Chinese adolescents (Jing *et al*., 2014). Comparably in an American study, 99% of all households possessed at least one TV (Statistics Brain, 2015).

TV broadcasting of programmes has evolved through the years and new technologies have been used to broadcast programmes worldwide. Countries across the world, including Germany, Sweden, France, South Africa and many more, are all engaged in converting their broadcasting communications from analogue to digital signal (O'Leary, Puigrefagut & Sami, 2006). Since the late 1920s TV broadcasting companies have used analogue signals to broadcast programmes to people worldwide. Analogue signals are messages conveyed by the broadcast signal using deliberate variations in frequency of the signal which the TV translates into a picture and sound (Ament, 2007; Bellis, 2011; Sandberg, 2012). Presently many broadcasting companies have and are still changing to digital TV, which transmits the information for sound and video as digital signals to a decoder/set-top-box/converter (Brain, 2011). Digital TV has become the most popular way of transmitting information to TV using a decoder to convert the information into an image on the TV (Department of Communications [DOC], 2008; Wilson, 2011). In South Africa the migration of the broadcasting system from analogue to digital is underway, which should revolutionize the manner of broadcasting and give South Africa the opportunity to position itself alongside leading others (DOC, 2008; Fin24Tech, 2015; Go Digital SA, 2015). The advantages of digital TV are better quality pictures (as digital signal can support higher resolution pictures), and broadcasters are able to choose if they wish to include interactive content with the digital TV signal (DOC, 2008; Wilson, 2011; Go Digital SA, 2015). Digital broadcasting has huge impacts for new and cutting-edge technology allowing mobile devices, such as smartphones, tablets and

other devices, to interact with the digital services through the decoder via an IP network connection (Bernhaupt *et al*., 2012; Bernhaupt & Pirker, 2013).

The adjustments to the broadcasting sector have not been the only changes in the television industry; physical remote controls (PRCs) have also changed a great deal. Prior to the first PRC being developed, in 1950 by Zenith Radio Corporation, TV viewers would have to change the channels manually using the buttons on the TV. The first PRC was called "Lazy Bones"; and was connected to the TV set by a wire to control the TV remotely (Ament, 2007; Bellis, 2011). Remote controls assist viewers in their quest to find programmes (channel hopping) to satisfy their moods and mind-sets depending on the time of the day (Knoche & McCarthy, 2005; Berglund *et al*., 2006). Originally PRCs only had a few buttons, such as on/off and channels up/down, with the majority of the buttons being placed on the TV set, for example, the fine-tuning knobs (Omojokun *et al*., 2006; Ament, 2007). Currently most buttons appear on the PRCs, such as fine-tuning, volume up/down, and channel up/down with only a few buttons placed on the TV, for example, power on/off; it is due to these modifications that PRCs have become more complex to use and indispensable, and thus generally the only way to interact with the TV is through the PRC (Hafner, 2004; Omojokun *et al*., 2006). Audiences have become accustomed to using PRCs and any alterations to the design of these devices should not interfere with the main activity of TV viewing (Berglund *et al*., 2006; Kimman *et al.*, 2011).

Since the appearance of the first commercial PRC the number of PRCs per household has gradually increased from one remote to upwards of three remotes as many household devices (e.g. DVD player, surround sound, etc.) require PRCs to operate them (Kimman *et al.*, 2011; Bernhaupt & Pirker, 2013). Inherent problems associated with PRCs are: too many buttons available to accomplish a variety of tasks (Cooper, 2008); button sizes have been reduced (are small) to allow for more buttons to be placed on the PRC (Cesar, Chorianopoulos & Jensen, 2008); overloaded functionality that users seldom use which results in cumbersome devices with difficult-to-use user interfaces (UIs) (Lee *et al*., 2008); and infrared capabilities that require a clear line-of-sight to control devices (TV) and have a limited range of about ten meters making communication from a great distance problematic (Layton, 2011). The combination of widely varying remote control devices and interaction patterns makes it difficult for any PRC to provide an effective and enjoyable user experience (Omojokun *et al*., 2006). Due to these complexities, usability problems have emerged. Usability contributes to the quality of a user's experience when interacting with a product or system and is mainly concerned with the design features of interactive products, and how well users can use the system's functionality (Sanguinetti *et al*.,

2003; Tullis & Albert, 2008). There are different types of TV viewers forming a large heterogeneous group of physical remote control (PRC) users, and digital TV and technological devices should support users with varying abilities, and cognitive and physical skills (Eronen, 2003). It is vital that the needs of users are understood in order for usable and enjoyable devices to be created (Bernhaupt *et al*., 2008; Pan & Ryu, 2009).

Many digital TV broadcasting companies have followed the trend of using remote control applications on smartphones; to control TVs. Sky+ Remote Record is an example of a virtual remote control (VRC) service using GPRS, 2.5G or 3G phones and DigiTV (Berglund *et al*., 2006; Nebula Media Solutions, 2011; Bernhaupt & Pirker, 2013; Sky, 2015). VRCs are becoming more widespread and introduce touch gestures, a new interaction technique (Saffer, 2008), to the TV viewing space since users engage with touchscreen devices to operate and interact with the TV (Bernhaupt *et al*., 2012; Derthick *et al*., 2013). This technology allows a smartphone to be configured as a VRC for a device (TV decoder) and can control the decoder through the VRC (Sony Ericsson Mobile Communications AB, 2005; Leitner, Ahlstrom, & Hitz, 2007; Layton, 2011). Many TV VRC applications available on the internet are simply replicas of what digital TV PRCs offer (Bernhaupt & Pirker, 2013). The TV VRCs introduce the same usability issues appearing in digital TV PRCs which are not designed specifically to take advantage of the digital device (Bernhaupt & Pirker, 2013; Sky, 2015). Instead of navigating with numerous PRCs using multiple buttons and complex layouts, VRCs should enable users to simply gesture or touch the touchscreen device in order to interact with the smartphone application (Bernhaupt *et al*., 2012). There is a need for guidelines to be developed describing what functionalities and layout design will contribute to achieve better usability and an enhanced user experience for a digital TV VRC.

Mobile phones have evolved over the years and have moved from physical numerical keypads to virtual keypads with high resolution touchscreen LCD (Liquid Crystal Display) interfaces (Nashel & Razzaque, 2003). In South Africa there are upwards of 58.8 million mobile phone users, with 91.7% of South Africans being smartphone users (MobiForge, 2014; Thomas, 2014). As the smartphone penetration increases worldwide these ubiquitous devices provide a natural tool for interaction between VRCs and various devices (Epelde *et al*., 2009; Wang *et al*., 2009). Given that mobile phones are abundant computational devices that are: nearly always available; universally connectable providing fast and reliable communication from almost anywhere in the world, both indoors and outdoors using infrared (IR) and Bluetooth for short range communication protocols, and wireless networks for long range communication protocols

(Barros, Benini & Zuffo, 2006; Roduner *et al*., 2007). Most mobile phone users are also TV viewers and the UX of mobile phones affects the experience of TV and vice versa, therefore consistency across products is an important design factor for TV interaction (Koskela & Väänänen-Vainio-Mattila, 2004; Pan & Ryu, 2009). For the purposes of this research smartphones are characterised as mobile phones with touchscreens that can function as a computer. A touchscreen smartphone has the potential to host a VRC and is an alternative to building a brand new digital device or PRC. The technology is available to allow users to control their digital TV decoder with a mobile device via an IP network as described by Lo, Lin and Chen (2006). The research outcome was a media centre responsible for complex multimedia tasks (transcoding and broadcasting digital content) to allow users to remotely command their decoders via an IP network (Lo *et al*., 2006). Similarly Pennington *et al*. (2013) patent suggested a remote control user interface system and method for enabling a handheld device to control an application on another device (TV). Simon, Comunello and Von Wangeheim (2013) proposed a way to reuse (transmit) the data coming from the digital TV broadcast onto a mobile device without the need for internet access, in order to allow for an interactive digital TV experience through a second screen.

1.2 Problem Description

TV PRCs have many usability problems associated with them: they have too many buttons, some of which are too small for users with big fingers; complex labels that are often misunderstood; and features that are not always used yet they are always visible and take up space on the PRC (Cesar *et al*., 2008; Lee *et al*., 2008). The evolution of technology for TV PRCs and broadcasting companies has amplified the complexity of remote control UIs (Nichols & Myers, 2003; Pan & Ryu, 2009). The migration from analogue to digital broadcasting allows more channels and functionality to be available to users (and more remote controls) which has added to the increased complexity of PRCs (Cooper, 2008; Bernhaupt & Pirker, 2013). Remote controls have many usability issues which may be resolved through the use of touchscreen technology (Wang *et al*., 2009).

Mobile phones are prevalent in society and are highly common devices that are moving away from the usual alphanumeric physical buttons towards touchscreen technology (Myers, 2004; Hess, Kustermann & Pipek, 2008). This evolution of mobile phone technology has the capacity to support digital TV VRCs and software updates allowing a plethora of interface options in comparison to TV PRCs (Lo *et al*., 2006; Pennington *et al*., 2013; Simon *et al*., 2013). Hence to inform the design of technology in everyday life, a move of the user interface design of TV

PRCs onto a smartphone with increased processing power and better input-output capabilities can be used to help improve the TV PRC usability (Myers, 2004; Bernhaupt *et al*., 2008). The move to smartphones as a second screen to the TV viewing process is aligned with the growing trend to use dual-display interaction whereby users watch a programme via the TV screen and have a second screen (smartphone/device) which they interact with and simultaneously control content, data and information presented on the TV (Cooper, 2008; Simon *et al*., 2013). The usability of these interfaces is a key issue in this research, as a product that is usable creates a good impression thus increasing its customer base and therefore its sales (Nielsen, 1993). Many mainstream companies, such as Sky, Apple and Digi TV, have found new ways in which to use the smartphone as a way to interact with devices, such as the decoder, using a VRC; but have not taken full advantage of the capabilities afforded by these devices and have for the most part replicated poor design of TV PRCs with the associated usability issues onto the VRC (Nebula Media Solutions, 2011; Sky, 2015).

To the best of the researcher's knowledge and what can be deduced is that there is a lack of literature offering guidelines on VRC interface design. This research looks at a single case of a popular digital satellite TV company in South Africa as a focal point for this research. There is a need to explore this area of research in order to create guidelines that will influence the user interface design for digital TV VRCs on touchscreen smartphones in order to support good usability and enhance user experiences. This research study specifically considers a touchscreen as the mobile device due to their increasing popularity and sales (Gartner, 2013).

1.3 Problem Statement

It has been observed by the researcher that developers have not taken full advantage of the digital TV VRCs and the technology afforded by touchscreens; all they have done is replicate the TV PRC along with its usability issues hence there is a need for guidelines to assist them in overcoming the usability issues related to their user interface design and functionality.

1.4 Research Objectives

The objective of this study is to create a set of guidelines that can be used to assist in the user interface design of digital TV virtual remote controls via touchscreen smartphones. These guidelines, will ultimately aim to provide for an enhanced user experience when interacting with these virtual remote controls.

The objective of this research is to determine the user interface design features that will contribute to an enhanced user experience for digital TV virtual remote controls.

In the context of this research, features are defined as various interface elements that help the user interact with the product. They typically represent a distinctive attribute or aspect of the interface such as placement of buttons on a screen or the ability to play a programme. These features will be used to inform the guidelines for the user interface design in terms of the functionality and layout design (UI).

The main research objective is supported by the following objectives:

1) **Determine the user interface design features needed when designing for touchscreen devices.**
2) **Understand the current usability issues of physical and virtual remote controls.**
3) **Ascertain the user interface design features digital TV virtual remote controls should contain.**
4) **Establish the impact the user interface design features have on the usability and user experience of a virtual remote control.**

1.5 Research Questions

The following section presents the main research question and sub-questions that will be answered in the various chapters in order to accomplish the research objectives.
The main research question for the study is:

What user interface design features will contribute towards an enhanced user experience for digital TV virtual remote controls?

The main research question is supported by the following research sub-questions:

RQ1: What user interface design features should be taken into account when designing for touchscreen devices?
RQ2: What are the current usability issues with physical and virtual remote controls?
RQ3: What user interface design features should digital TV virtual remote controls contain?
RQ4: What impact do the user interface features have on the usability and user experience of virtual remote controls?

1.6 Research Methodology

In undertaking this research, a Design Science Research (DSR) approach is followed, which involves the creation of artefacts to reach a solution to the problem under investigation (March & Smith, 1995; Hevner *et al*., 2004; Carlsson, 2006; Hevner, 2007; Peffers *et al*., 2007). The term artefact is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally (Simon, 1996). DSR is viewed as an appropriate approach since this research aims to solve a real life problem regarding the usability of digital TV PRCs and digital TV VRCs, and intends to create a set of guidelines (the artefact) that better inform a usable user interface design for digital TV VRCs on touchscreen smartphones in order to enhance the user experience.

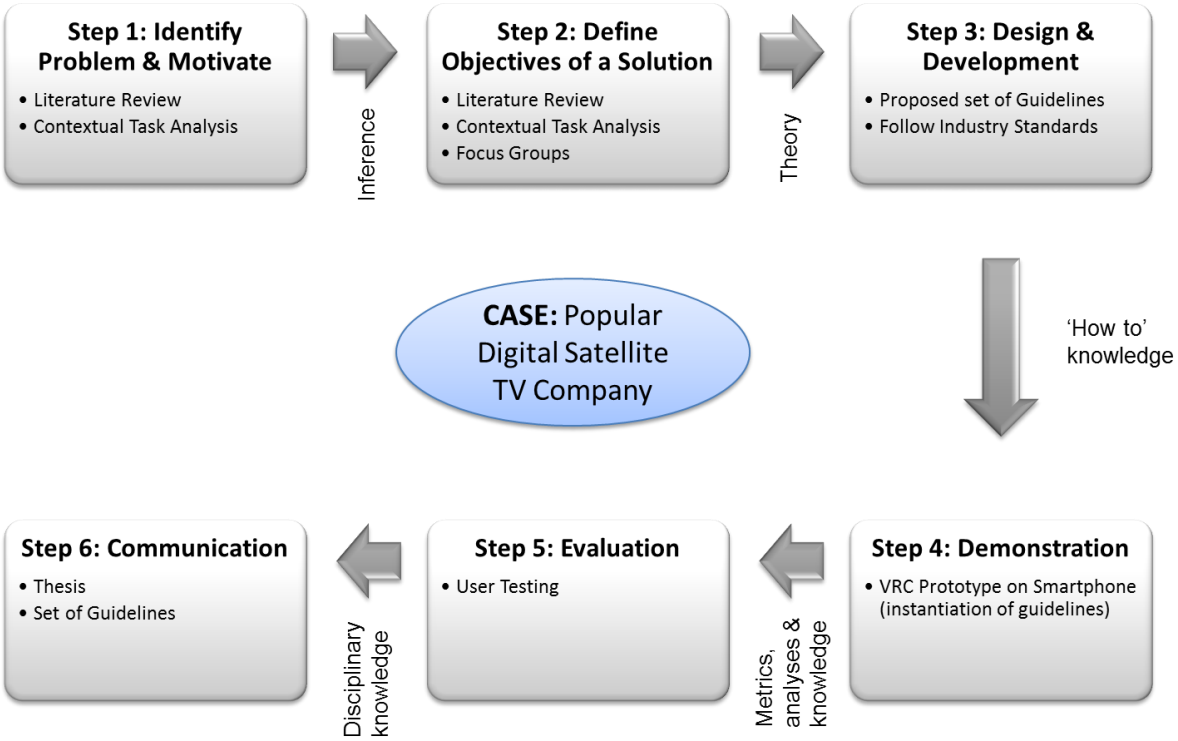


Figure 1.1: Design Science Research Process (Adapted from Peffers et al., 2007)

A single case regarding a popular digital satellite TV company is used for this research. This research follows Peffers *et al*. (2007) Design Science Research Process (DSRP) model which comprises six steps, namely: problem identification and motivation, objectives for a solution, design and development, evaluation, and communication (Figure 1.1). The research method is presented over multiple chapters in order to answer the research question and sub-questions. Step one of the DSRP, identify problem and motivate, is covered in Chapter 1 where the problem space is introduced; in Chapter 3 through the review of literature regarding mobile human computer interaction (MHCI); through the usability of PRCs and VRCs in Chapter 4; and through the contextual task analysis (CTA) in Chapter 5. The second step, define objectives of a solution, draws on the information gathered from Chapter 1, 3, 4 and 5 and builds upon this knowledge in Chapter 5 and the brainstorming focus groups in Chapter 6 to further define the solution to the identified problem. Step three, design and development, is completed in Chapter 7 where the artefact in the form of a set of user interface design guidelines is proposed and a VRC prototype is produced based on the proposed guidelines. The demonstration of the artefact (proposed guidelines used to build the VRC prototype), step four, also transpires in Chapter 8. Step five, the evaluation, is used to observe and measure how well the artefact (proposed guidelines) supports a solution to the defined problem; this was accomplished in Chapter 8. The usability testing evaluates users completing tasks, using the digital TV VRC prototype, in order to ascertain if the proposed user interface design guidelines that informed the VRC prototype created a successful user experience. The final step (step six),

communication, was shown throughout the dissertation; Chapter 9 in particular summarises and explains the overall outcome of this research study.

1.7 Scope and Constraints

This research is focused on creating a set of user interface design guidelines for a single case of a popular digital satellite TV company within South Africa; all other digital TV broadcasters were excluded. The study was applied to an English speaking population and it is not known how people from different cultures would respond to the digital TV VRC, thereby affecting the outcome of the usability testing and ultimately the user interface design guidelines. The sample size for the research was limited to small groups and never exceeded ten people per method. There is great value in the qualitative data that was revealed in order to create the user interface design guidelines. The assumption for this research is that the user interface design guidelines created can be applied to other digital TV VRCs. The research does not investigate voice controlled components.

1.8 Ethical Considerations

Given this study involves humans as the subjects, all research complies with the Rhodes Ethical Standards and Procedures Policy for Research on Human Subjects to ensure the protection of the rights and dignity of the users. The ethics of research relates to what is right and what is wrong when conducting research and particular types of conduct are morally acceptable while others are not (Vallance, 2005). Therefore, in conducting this research, the following ethical considerations are applied:

Ethical Approval: Before conducting the research, ethical approval was requested from the institutional and review board for ethics in the Information Systems department at Rhodes University. The ethics number for this research is IS12-03.

Informed Consent: This is considered an important standard which oversees the relationship between the researcher and the participants (Vallance, 2005). Participants were provided with enough information to allow them to determine whether they wanted to be a part of the research or not. Letters were given to each participant before any of the studies began to inform them of the purpose of the research, the reasons for their involvement in the research, and the expected uses of findings from the research. The participants in this study were asked to sign an informed consent form before any of the research studies took place. A copy of the informed consent form that was used is available in APPENDIX A.

Confidentiality and Anonymity: All participants were assured that all their personal details would be kept anonymous and remain confidential, as suggested by Vallance (2005). A coding system was used to keep the participants details personal, for example, participant 1 was used to identify the first person participating in the research.

Protection of Participants from Undesirable Effects: Participants were treated in a morally acceptable manner to guard them from being manipulated or treated as experimental numbers rather than human beings (Vallance, 2005).

1.9 Outline of Chapters

The dissertation chapters in sequential order are organised as follows:

Chapter 1: Introduction

This chapter introduces the research study. The research context is outlined to offer a background to the research. The goals of the research as well as the methodology are described and the scope of the research is delineated.

Chapter 2: Research Methodology

The research methodology employed to create user interface design guidelines for usable digital TV virtual remote controls via touchscreen smartphones is explained. The applied Design Science Research approach is also outlined.

Chapter 3: Mobile Human Computer Interaction

This chapter describes user experience and mobile user experience as well as mobile human computer interaction (MHCI). In particular, this chapter considers the usability principles that are used to measure user interfaces and further describes the physical, logical, graphical, and natural user interfaces (PUI, LUI, GUI, and NUI). The aim of this chapter is to gain an understanding of the domain theory for MHCI and to answer the first research sub-question.

Chapter 4: Remote Control Usability

This chapter highlights the current usability issues of digital TV physical remote controls (PRCs) and digital TV virtual remote controls (VRCs) in order to answer the second research sub-question.

Chapter 5: Contextual Task Analysis

This chapter describes the context in which users watch TV and operate PRCs in an attempt to identify the frequent tasks completed by users while operating PRCs. This chapter further seeks to understand what functionality currently supports users' activities or negatively affects the UX when operating PRCs and the functionality that should be included into digital TV VRCs. This chapter aims to answer a hybrid of the second and third research sub-questions.

Chapter 6: Brainstorming Focus Groups

This chapter explores new ideas for digital TV VRC functionality that may enhance the UX for users and improve upon current PRC functionality. The most commonly used touchscreen interaction techniques are revealed and ideas regarding the representation of certain UI elements on VRCs are ascertained. This chapter aims to answer the third research sub-question.

Chapter 7: Proposed Guidelines

This chapter proposes a set of user interface guidelines for creating usable digital TV VRCs on touchscreen smartphones that draws from all the literature reviews and results from the prior research chapters. The proposed user interface design guidelines are used as a foundation to build a digital TV VRC prototype design. This chapter aims to answer the fourth research sub-question.

Chapter 8: Prototype Evaluation

This chapter evaluates the VRC prototype through usability testing in order to gather users' experiences regarding the VRC prototype usage. This testing validates or invalidates the application of the proposed set of user interface design guidelines.

Chapter 9: Discussion and Conclusion

This chapter concludes the research by summarising the findings of the research and emphasises areas that require future investigation and exploration. The conclusions of the research are delineated and future research areas are highlighted.

Chapter 2 Research Methodology

2.1 Introduction

The purpose of this chapter is to describe the research methodology that is used to structure this research dissertation and address the research problem. This chapter discusses design science research and how it applies to this research. Despite the fact that related work precedes the use of the term (design science), it is often presented as a relatively new approach within the Information Systems (IS) discipline (Hevner *et al*., 2004). The origin of design science research is reviewed and various design science research approaches are discussed. The guidelines from the various design science approaches were considered and the model by Peffers *et al*. (2007) selected.

2.2 Overview of Design Science Research

Design science research activities have been undertaken for many years and by many authors, such as Hevner *et al*. (2004) and Peffers *et al*. (2006). The IS view of design science has its roots in Simon's (1996) The Sciences of the Artificial, an exploration of the study of man-made things in which design thinking plays an important role. It is argued by Simon (1996) that in contrast to the natural sciences, for example, biology or physics, a significant source of knowledge can be found in the human-constructed world of the 'artificial'. Disciplines that come to grips with questions of design include: all forms of architecture, medicine, engineering, aspects of law, and business (Simon, 1996). The difference between the natural sciences and artificial sciences are that, natural sciences remain concerned with truth and necessity whereas artificial sciences are focused on usefulness and possibility (contingency). The common thread between these two contrasting fields is the idea of an artefact. Simon (1996) also argued that validity of such approaches has yielded to the importance of the natural sciences. Consequently, the artefact has been overlooked. Ultimately Simon (1996) calls researchers to incorporate these artificial sciences, in particular design, as an approach for undertaking research (Hill, 2009; Prestopnik, 2013). Since Simon's discoveries, design science has been examined within IS as a research method (Hevner *et al*., 2004; Gregor, 2006; Gregor & Jones, 2007; Peffers *et al*., 2007) as well as used for conducting research on IS topics.

There are many varieties of philosophical approaches for "ways of knowing", which have generally been separated into positivism, interpretivism, realism, hermeneutics, critical theory, and phenomenology (Saunders *et al*., 2009). Typically, the chosen research strategy and the methods for research activities depend on the research philosophical stances (Saunders *et al*.,

2009). These divisions in philosophical stances do not distinguish another research paradigm that is aligned toward practical problem solving which is Design Science Research (DSR). This research study has chosen DSR as the philosophical approach. Table 2.1 shows a comparison between two philosophical approaches with DSR to demonstrate the difference in the way DSR views the world (Vaishnavi & Kuechler, 2015).

Table 2.1: Philosophical Assumptions of Three Research Perspectives

Research Philosophy			
Basic Belief	Positivist	Interpretivist	DSR
Ontology	A single reality Knowable, Probabilistic	Multiple realities, socially constructed	Multiple, contextually situated alternative world-states Socio-technologically enabled
Epistemology	Objective dispassionate, Detached observer of truth	Subjective (i.e., values and knowledge emerge from the researcher-participant interaction)	Knowing through making: objectively constrained construction within a context, Iterative circumscription reveals meaning
Axiology: what is value	Truth: universal beautiful, prediction	Understanding: situated and description	Control; creation; progress (i.e., improvement); understanding

The IS view of design science is an approach to academic study where design activities are framed as scientific activities (March & Smith, 1995). The design, development and evaluation of information technology (IT) artefacts have become a vehicle for knowledge generation (Nunamaker & Chen, 1990; March & Smith, 1995; Simon, 1996; Iivari, 2007; Peffers *et al*., 2007). The design science approach involves the formation of artefacts to reach a solution to a problem under investigation (Hevner *et al*., 2004; Peffers *et al*., 2007). The word artefact is used to depict something that is artificial, or man-made, as opposed to something that occurs naturally (Simon, 1996). Hevner *et al*. (2004) describe IT artefacts as, "*constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems)*." Constructs are vocabulary and conceptualisations that enable communication and the description of problems, constraints, solution components and objectives for the designed artefact (March & Smith, 1995). Models use these constructs to represent a situation (problem) and its solution space. Methods are guidelines that are used to share the solution space and enable the construction of instantiations, which are computer-based systems implemented within an organisation (March & Smith, 1995). Thus from an IS perspective, an IT artefact can be more than just an instantiated information

system or technology (Prestopnik, 2013). Its basis deals with how a product intends to work and how it can be modelled and evaluated through the creation of artefacts (Vaishnavi & Kuechler, 2015). It is through the "build" and "evaluate" processes, that the researcher gains both familiarity and an understanding of the study area and develops likely solutions to the problems (March & Smith, 1995; Peffers *et al*., 2006). This approach uses knowledge generated from deep, explanatory theories of how humans interact with machines, and uses mainly qualitative rather than quantitative methods. The challenges with the design science approach are the difficulties that may arise from the difficulty and challenges of everyday situations and the resistance to experimental control, as well as the large amounts of data that arise from the various data gathering methods used such as ethnographic studies (Collins, Joseph & Bielaczyc, 2004).

A fundamental belief of the IS view of design science is that *"design activities are scientific activities, as long as they are properly framed within: an appropriate context, around theory and observations that can make and test assertions about the world"* (Prestopnik, 2013). At the same time, design science claims and assessments are noticeably different from those established in the natural sciences. Instead of testing how well a statement clarifies something about the world, claims and assessments in design science are about ascertaining success or failure (March & Smith, 1995; Simon, 1996; Iivari, 2007; Peffers *et al*., 2007). According to Hevner *et al*. (2004), artefacts created through design science research are a vital academic output because they determine feasibility, enabling particular evaluation of an artefact's appropriateness to its intended purpose (Prestopnik, 2013). They also enable researchers to learn about the real world, how the artefact affects it, and how users accept it. Pirkkalainen's (2015) research dealt with emergent design science research projects in information systems that aimed to manage the role of the researcher within these projects. The aim being to create meta-level monitoring in order to increase the practical value and contribution of the research attempts. It is vital to monitor the practical implications of using design science research.

Hill's (2009) research addressed a significant and persistent problem in Information Systems regarding the under-investment in the quality of customer information, and sought to develop and evaluate a framework (artefact) for producing financial models of the costs and benefits of customer information quality interventions. The design science research approach was used to complete the research through: a review of the literature, semi-structured interviews, knowledge gathering from other disciplines, simulation study to evaluate and refine the framework, and an evaluation of existing published material. Similarly, Scott (2012) used a design science research

(DSR) approach for her study towards a coherent practice in capstone courses for IS majors. DSR was used to develop a theory as an abstract artefact which in turn guided the design of a capstone course as a physical artefact.

Design science is viewed as a suitable approach for this research. Gregor & Hevner's (2013) research regarding the positioning and presentation of design science research for maximum impact was considered when structuring the research. The research aims to create a set of user interface design guidelines (artefact) to solve a real world problem regarding remote control usage. The guidelines are instantiated (implementation) through a VRC prototype, in order to reach a suitable solution. The implementation was tested on users to see if an application built following the proposed set of user interface design guidelines would offer a good user experience and be deemed successful or not. DS research offers IS researchers an important example for conducting pertinent, yet rigorous research that is similar to an applied research technique (Peffers *et al*., 2006).

2.3 Design Science Research Process Models

The following section describes DS approaches that all have a similar viewpoint. The framework proposed by March and Smith (1995) was driven by two complementary but distinct research outputs and research activities. The research outputs were based on design science research, and these artefacts could be in the form of constructs, models, methods and instantiations. The second part of their framework was based on broad types of design science and natural research activities: build, evaluate, theorise, and justify (March & Smith, 1995). The IS research builds and evaluates models, constructs, methods, and instantiations. It also theorises about these artefacts and attempts to validate these theories. The building and evaluating have DS intent whereas the theorising and validating have natural science intent (March & Smith, 1995).

Hevner *et al*. (2004), building upon March and Smith (1995) proposed the Information Systems Research Framework (ISRF) to understand, execute, and evaluate IS research combining behavioural-science and DS approaches.

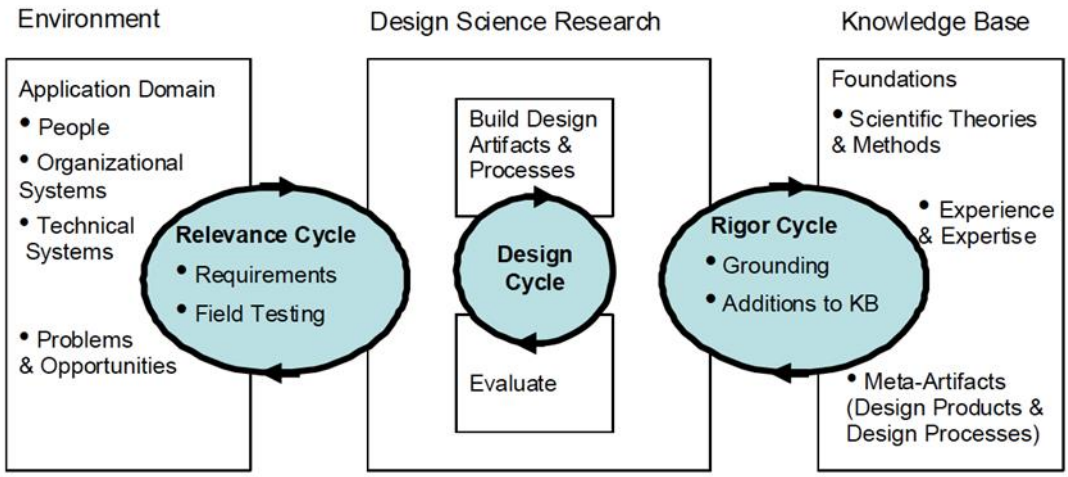


Figure 2.1: Design Science Research Cycle (Hevner *et al*., 2004; Hevner, 2007)

Hevner (2007) used the ISRF as the foundation of Figure 2.1, which draws particular attention to the three cycles, namely: the relevance cycle, rigor cycle, and design cycle. The relevance cycle includes the environment (application domain) which comprises people, organisational systems, and technical systems as well as the opportunities and problems of the environment (Hevner *et al*., 2004; Hevner, 2007). The requirements and field testing for the relevance cycle is iterative and dependent on the results from this phase. The rigor cycle provides previous information to the research project to warrant its innovation (Hevner, 2007). The foundations for this phase are: knowledge of scientific theories and approaches, experience and expertise in the application domain, and knowledge of existing artefacts and processes in the application domain. The design cycle is the stage at which the DS research takes place. Artefacts are designed and built and specific processes are followed in order to evaluate the artefact (Hevner, 2007). The requirements are inputted from the relevance cycle and the design and evaluation theories and methods are drawn from the rigor cycle.

The following seven guidelines from Hevner (2004) help to explain the stages of the design science research in the Information Systems discipline as it pertains to this research study (Table 2.2).

Table 2.2: Design science guidelines (adapted from Hevner, 2004)

Guideline	Description of guideline in accordance with the study
Design as an artefact	Design science research must produce a viable artefact in the form of a construct, a framework, a method or an instantiation. *This research aims to develop a set of user interface design guidelines that will contribute to an enhanced user experience for digital TV virtual remote controls.*
Problem relevance	The objective of design science research is to develop technology-based solutions for important and relevant business problems. *The set of guidelines*

	to be created aim to overcome and improve upon the current usability issues concerning remote control usage for digital TV watching in order to enhance the UX.
Design evaluation	The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods. *The set of guidelines will be evaluated through the creation of a prototype that will undergo user testing by means of participant observations and user surveys.*
Research rigour	Design science research relies on the application of rigorous methods in both the construction and the evaluation of the design artefact. *In this research study the guidelines are constructed by doing a literature review of mobile human computer interaction as well as current usability issues related to physical remote control and virtual remote controls. A contextual task analysis and brainstorming focus groups were arranged for further rigour.*
Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations and/or design methodologies. *This study will propose a set of user interface design guidelines that will inform the development of digital TV virtual remote controls on touchscreen smartphones to create an enhanced user experience and to overcome some of the usability issues experienced with physical remote controls.*
Design as a search process	The search for an effective artefact requires utilising the means available in order to reach the desired ends while satisfying laws within the problem environment. *The set of guidelines need to exist within and abide by the usability standards that are common practise in mobile human computer interaction as well as be suitable for touchscreen smartphones within the digital TV watching environments.*
Communication of research	Design-science research must be presented effectively both to technology-oriented, as well as, to management-oriented audiences. *This research is to be communicated to key individuals involved in the digital broadcasting industry that make use of digital TV virtual remote controls. The goal is to publish the results of this research in journals and conference papers for feedback and knowledge sharing.*

Carlsson (2006) argues that Hevner *et al*.'s (2004) IS design science framework has a strong bias towards the IT artefact and offers an alternative framework for IS design science research (Figure 2.2) based on critical realism that "*builds on that the aim of IS design science research is to develop practical knowledge for the design and realization of different classes of IS initiatives, where IS are viewed as sociotechnical systems and not just IT artefacts*" (Carlsson, 2006). Therefore, broadening Hevner *et al*.'s (2004) view on IS design science research.

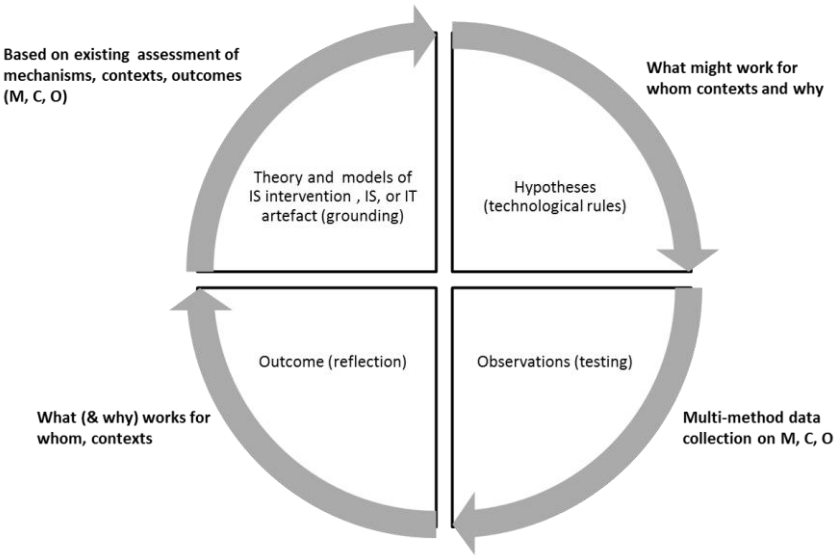


Figure 2.2: IS Design Science Research Cycle (Carlsson, 2006)

Peffers *et al*. (2007) developed a theoretical process and mental model for implementing design science research and presenting it. The proposed Design Science Research Process (DSRP) is consistent with prior literature (Hasan, 2004; Hevner *et al*., 2004; Hevner, 2007; March & Storey, 2008; Ellis & Levy, 2010) and includes six steps: problem identification and motivation, objectives for a solution, design and development, demonstration, evaluation, and communication (Figure 2.3) (Hevner *et al*., 2004; Hevner, 2007). The DSRP is further explained below and the iterative nature of the DSRP is represented by the arrows between the six steps (Peffers *et al*., 2007).

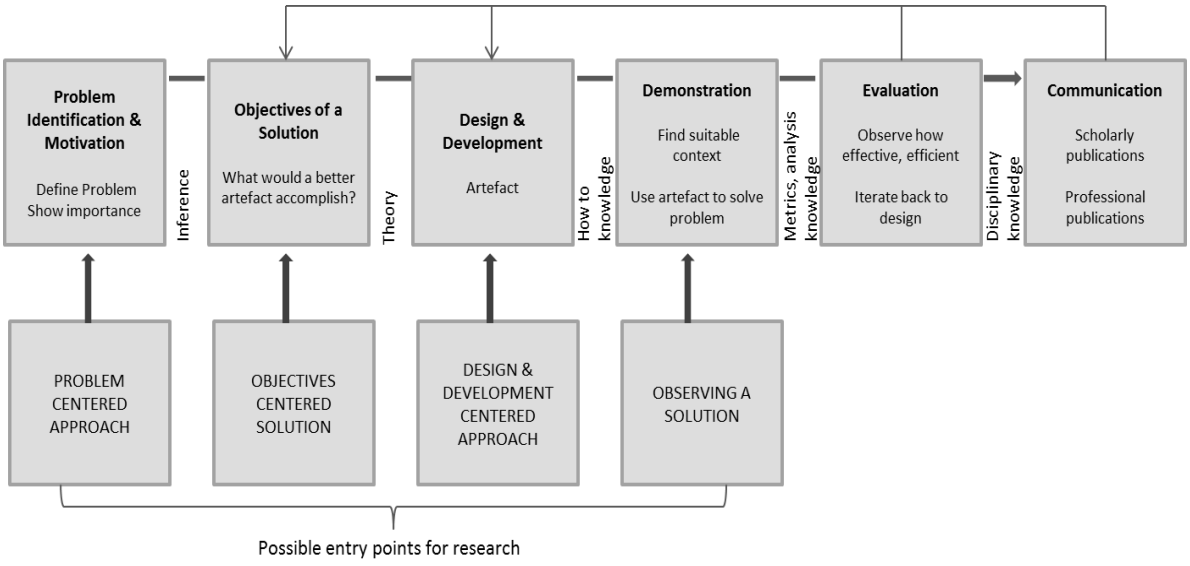


Figure 2.3: Design Science Research Process (DSRP) Model

When drawing parallels between March and Smith (1995), Hevner *et al*. (2004), Carlsson (2006), Hevner (2007), and Peffers *et al*. (2007) design science approaches it was noted that they

were very similar. All the approaches had similar processes but the authors named the stages slightly differently. In particular, Hevner *et al*. (2004) describes *design as an artefact* similarly Peffers *et al*. (2007) addresses *design and development*. Both these guidelines share the notion that an artefact in some shape or form must be created, be it a construct, model, method or instantiation. Similarly March and Smith's (1995) framework suggests the same research outputs (construct, model, method or instantiation). Hevner *et al*. addressed *problem relevance* and Peffers *et al*. comparably discussed *identifying the problem and motivation* for a solution. Equally these authors set out to develop solutions for specific problems and tried to define the complexity of the problem as well as solutions that would be the most viable to solving the said problems (Hevner *et al*., 2004; Peffers *et al*., 2007). *Design as a search process* (Hevner *et al*., 2004), *build* (March & Smith, 1995), and *define objectives for a solution* (Peffers *et al*., 2007) can be likened since these authors maintain that understanding of the state of problems and existing resolutions will help researchers to create effective (build) artefacts that exist within the bounds of limitations set for the environment, as well as abide by laws of the problem space. Carlsson (2006) encourages that part of the research is based on existing assessments of contexts and outcomes. *Research rigour* as defined by Hevner *et al*. (2004) refers to applying thorough methods in both the building and assessment of the designed artefact. Similarly Peffers *et al*. (2007) recommended the use of appropriate methods, such as experimentation, simulation, case studies, among others, in order to *demonstrate* the efficiency and usefulness of the artefact to solve the defined problem. The *design evaluation* Hevner *et al*. (2004) discussed follows the *demonstration* guidelines that Peffers *et al*. (2007) recommended and is ratified by their *evaluation* guideline, which is also confirmed by March and Smith (1995) and Carlsson (2006) in the observations phase. An artefact must be thoroughly demonstrated using well-executed methods through the process of comparing the objectives or the solution, to the actual observed results, from the use of the artefact. Hevner *et al*. (2004) and Peffers *et al*. (2007) both advocate the *communication* of the *research contributions* to all audiences so that the usefulness, effectiveness, originality, and rigour of the designed artefact are known to all. These authors insist on the importance of clear and verifiable contributions (artefact) in the subject domain.

2.4 Design Science Research Process followed in this Study

The DSRP as outlined by Peffers *et al*. (2007) and utilised by Gancega *et al.* (2012) was used to structure this research and was used, in particular, to deal with a real life problem (Figure 2.4). The real life problem refers to overcoming some of the current usability and user experience issues of digital TV PRCs through the improved design of a usable digital TV VRC user interface that follows the guidelines specified in this research. As stated in section 2.3, the

similarities drawn between March and Smith (1995), Hevner *et al*. (2004), Carlsson (2006), Hevner, (2007), and Peffers *et al*. (2007) show that all of these approaches have similar intent as well as the same basic goal, to create an artefact that solves a real problem.

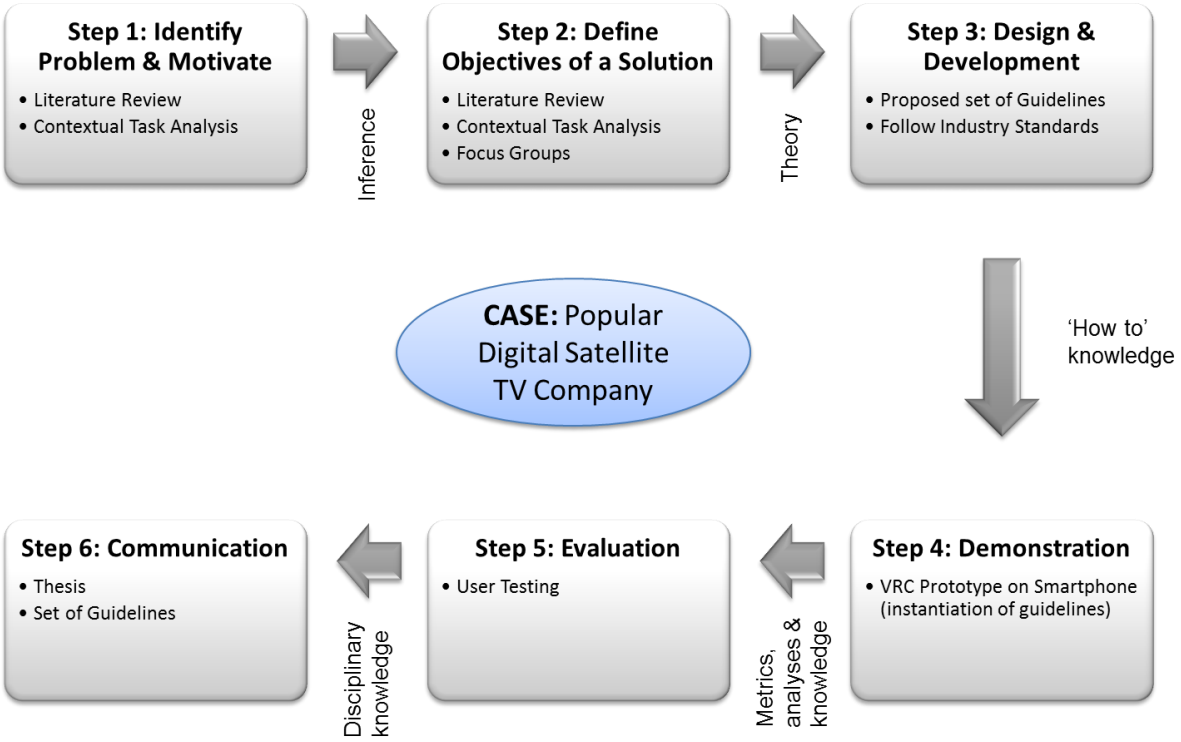


Figure 2.4: Design Science Research Process (Adapted from Peffers *et al*., 2007)

2.4.1 Identify Problem and Motivate

The first step of the DSRP is to understand the research problem and validate the importance of a resolution (Peffers *et al*., 2007). The problem definition will be delineated conceptually and will be used to develop a solution, in the form of an artefact, which will help to encapsulate the problem's complexity. The justification of an 'artefactual' resolution compels the researcher and the audience of the research to uncover a solution and accept the results; which helps them to comprehend the thinking associated with the researcher's understanding of the problem. Knowledge of the state of the problem and the importance of its solution are crucial to this DS research step. The first step in Peffers *et al*. (2007) process model is covered in Chapter 1, Chapter 3, Chapter 4, and Chapter 5. In Chapter 1, the problem space is introduced and the potential for technology to support the new solution is discussed. Chapter 3 is a literature review that develops the knowledge needed to understand usability and user experience for touchscreen smartphones as well as the interfaces associated with them. Chapter 4 addresses the actual problem space by highlighting the current usability issues with physical remote controls (PRCs) and virtual remote controls (VRCs) through a literature review. This chapter (Chapter 4) also contributes to the motivation for a solution (artefact) to the problem space. The aim of Chapter 5 is to understand the problem in context through the contextual task analysis (CTA) and to

identify problems using PRCs. All four of these chapters contribute to identifying the problem space and motivate for the importance of a solution to resolve the current usability issues of PRCs.

2.4.2 Define Objectives of a Solution

The objectives of a solution (artefact) should be inferred rationally from the problem definition (Peffers *et al*., 2007). The objectives can be: quantitative, for example, requirements in which a necessary solution would be better than current solutions; or qualitative, for example, a new artefact is expected to validate solutions to problems not previously addressed. Knowledge of the state of problems and existing solutions as well as their usefulness, if any, is required to complete the second step of the DSRP. The second step in this research is based on the conclusions drawn from Chapter 3, Chapter 4, and Chapter 5, and is further developed during Chapter 5 (CTA) and the brainstorming focus groups in Chapter 6. The aim of Chapter 5 (apart from understanding the tasks users completed with PRCs) is to understand what functionality supports users' activities, or negatively affects the UX, when operating PRCs to understand what functionality should be catered for within VRCs. Chapter 6 aims to explore new ideas for VRC functionality that may enhance the UX for users and improve upon current PRC functionality, with the objective to create an artefact that solves the known problems regarding PRC usability and UX.

2.4.3 Design and Development

The third step of the DS research process is to create a solution in the form of an artefact (Peffers *et al*., 2007). Artefacts are broadly defined as constructs, models, methods, or instantiations (Hevner *et al*., 2004). The design and development step includes establishing the artefact's required functionality and its architecture and then producing the definite artefact. This step necessitates knowledge of theory that can be put forth as a solution. Chapter 7 follows the design and development of the artefact (step three) by combining the proposed user interface design guidelines (artefact), and building a prototype based on these proposed guidelines. The artefact is created for the single use case of a popular digital satellite TV broadcaster.

2.4.4 Demonstration

Once a solution or artefact has been proposed it is vital to demonstrate the effectiveness of the artefact to solve the defined problem (Peffers *et al*., 2007). This step could involve the use of simulation, experimentation, proof, case studies or other appropriate activities. The fourth step requires an effective knowledge of how to use the artefact to resolve the problem. Chapter 7

demonstrates the proposed user interface design guidelines (artefact) as they have been used to guide the interface design of the digital TV VRC on a touchscreen smartphone.

2.4.5 Evaluation

The fifth step of the DS research process is to study and assess how well the artefact supports a solution to the defined problem (Peffers *et al*., 2007). This process comprises of comparing the goals of the solution to actual observed results from the usage of the artefact during the demonstration (the fourth step). Knowledge of pertinent metrics and analysis techniques is required in order to correctly assess the artefact's capability as a solution to the defined problem. Types of evaluation of the artefact (in general) include but are not limited to: an assessment of the artefact's functionality with the resolution's objectives from step two; or objective quantitative performance measures such as client feedback, surveys or simulations. At the end of the evaluation process the researcher may wish to iterate back to step three (design and development) to try to increase the usefulness of the artefact or to persist to the communication step and leave further enhancements to subsequent research studies. Chapter 8 focuses on the evaluation of the research. This step is shown through usability testing that involves users completing a set of tasks in order to understand if the proposed user interface design guidelines are successful or not, in creating an enhanced UX.

2.4.6 Communication

The final step of the DS research process is to convey the problem and its significance; the artefact, its usefulness and originality, the precision and rigour of its design, and its effectiveness to researchers and other applicable audiences (Peffers *et al*., 2007). In order to fully communicate all the information correctly, knowledge of the disciplinary culture is vital. The sixth step was communicated through this entire dissertation and summarised in the concluding chapter, Chapter 9. The overall outcome of the research was explained and further research suggestions were made.

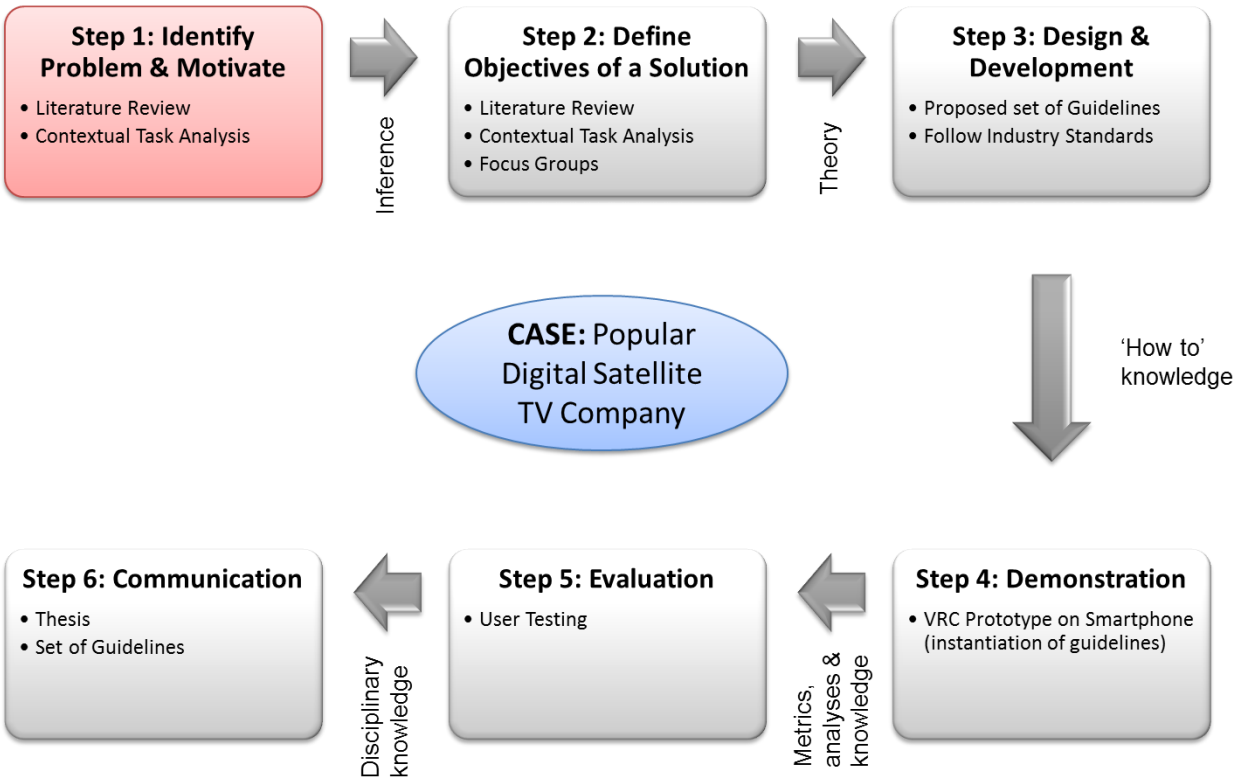
2.5 Conclusion

This chapter focused on the basis of design science research and the various design science research methods available. Design science is an appropriate choice for this study as it aims to solve a real world problem and to create a useful artefact as an outcome to the research. This research is structured by the design science process model as described by Peffers *et al*. (2007) which includes six steps and was applied to a single case of a popular digital satellite TV company.

Chapter 3 Mobile Human Computer Interaction

3.1 Introduction

Chapter 3 contributes to Step 1 of the DSRP model which pertains to identifying the problem and motivation for the research. This is completed through a review of the literature.



The purpose of this chapter is to gain an understanding of the domain theory for mobile human computer interaction (MHCI). Figure 3.1 depicts what will be covered in this chapter and how all the sections relate to each other. This chapter describes user experience (UX) and the factors that affect a user's experience and focuses on how mobile user experience (MUX) is linked to UX (Figure 3.1). This chapter also defines mobile human computer interaction (MHCI) as the study of how people interact with computers and the extent the devices are, or are not, developed for successful interaction with humans. MHCI is discussed as well as how it links back to human computer interaction (HCI) and the direct effect on mobile user interfaces (MUIs). The usability principles are considered which can be used to measure the user interfaces (UIs) of touchscreen mobile devices. The mobile user interface design (MUID) is reviewed in terms of the physical user interface (PUI), logical user interface (LUI), and graphical user interface (GUI) which are the interfaces that users interact with and ultimately have an effect on the MUX. Finally, the chapter discusses the natural user interface (NUI) as a way of interacting with touchscreen

devices which may alter how users experience these devices. An understanding of the challenges that touchscreen mobile devices and their environments bring to MHCI can assist in an improved MUID which ultimately affects the MUX. This chapter assists in answering the first research sub-question, "*What user interface design features should be taken into account when designing for touchscreen devices?*"

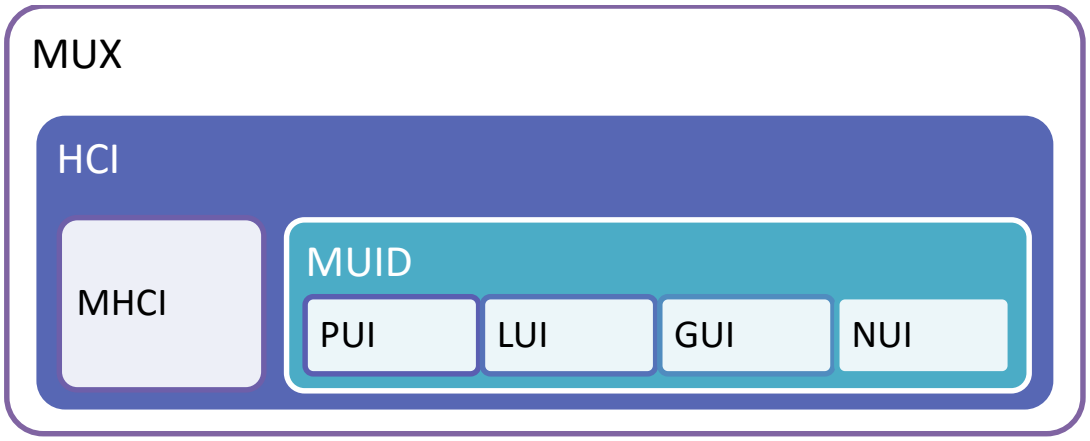


Figure 3.1: User Experience Components

3.2 User Experience

User experience refers to all aspects of how people use an interactive product (Alben, 1996): the way the product feels in their hands, how well they understand how it works, how well it serves their purposes, how they feel about it while they are using it, and how well it fits into their entire context in which they are using it (Alben, 1996). There are many different elements that comprise and affect an interaction/experience (Figure 3.2) such as: social factors, cultural factors, context of use, the user, and the product. The outcome of the combination of interactions result in the final user experience (Arhippainen & Tahti, 2003). UX encompasses all the internal and external factors affecting the user.

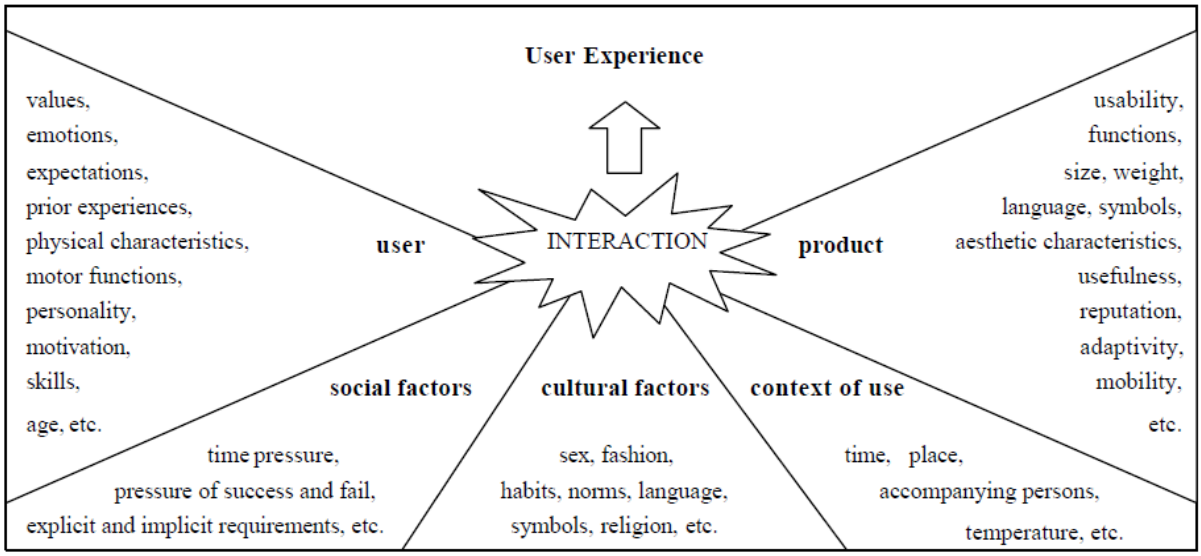


Figure 3.2: Factors affecting UX (Arhippainen & Tahti, 2003)

When users interact with products, they have inherent influencing factors, such as emotions, skills, and personalities. These are influenced by the context of use (time and place), cultural factors (fashion, norms and language), and social factors (time pressure and explicit requirements). The UID and particular design of a product's interface influences users' interactions and forms part of their UXs (Arhippainen & Tahti, 2003). The elements of products, such as usability, size, usefulness, adaptability, mobility, and features affect the user interaction and ultimately the UX. Identification of the elements of products that can be modified can help enhance the UX since these elements influence the interaction of users with products and ultimately affect the UX of the overall product. The elements of products that can be changed to be more appealing or more useful are highly important in UID as they affect UX. If they are changed in a way that improves the user interaction the likelihood of the resulting interaction will be a successful one and ultimately a positive UX.

Elements from Morville's (2004) honeycomb (Figure 3.3) must be considered when trying to enhance a user's satisfaction with mobile devices. The UX elements include being: useful, desirable, accessible, credible, findable, usable, and valuable. UIs should have useful purposes that fulfil users' needs when they make use of them (Morville, 2004). Without a use, the UI is pointless. It is also vital that the UI is easy to use (usable) and intuitive for users to know how they can utilise the UI to fulfil their needs.

Figure 3.3: The honeycomb of UX (Morville, 2004)

Maassen (2008) depicts similar elements (Figure 3.4) showing the relationships between: usefulness, usability, accessibility, visual design, interaction design, utility, information architecture, and the user.

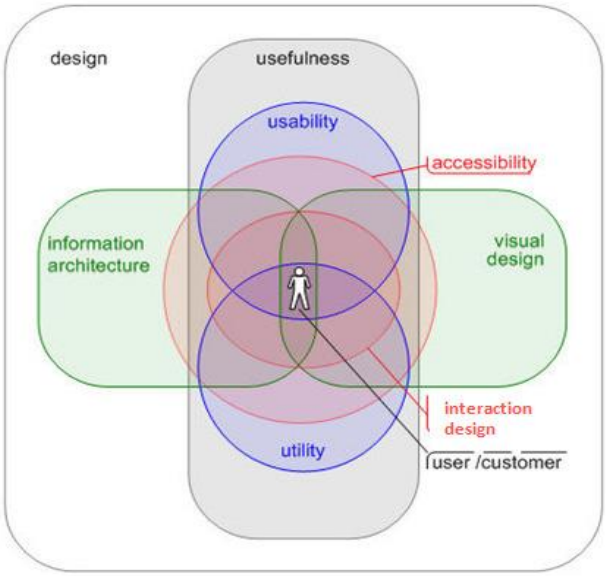


Figure 3.4: The relationship of UX elements (Maassen, 2008)

Maassen (2008) reiterates Morville's rational. However, Maassen bases usefulness upon utility and usability. He mentions it is important that the UI is able to give the exact kind of service users are expecting, and allows the users to reach their goals, in an easy manner, when using devices. Similarly Arhippainen and Tahti's (2003) model of the factors affecting UX (Figure 3.2) show usability and usefulness to affect the overall product, ultimately contributing to the UX. An improvement in any one of these factors (usefulness, usability or utility) through the UID, brings about a change that affects the UX.

Users do not necessarily want to have a UI that is just functional, but rather something that looks good, is fun and easy, and is desirable to use (Morville, 2004). Maassen, Arhippainen and Tahti, support Morville's need for a UI to be desirable, and this can be attained through a visual design that supports: clarity of information and features, enjoyable or interesting appearances of the interface, simplicity of tools and components, the joy of look and feel, and the visual hierarchy.

It is useless to have a UI that looks great and is highly usable and yet users cannot find features they are looking for within the UI (Morville, 2004). Thus, users need to be able to find (findable) features within the UI, for example, good navigation or search features helping users to find particular items. Interaction design is used to make features more findable by responding to design issues of: workflow, clarity, logic, and simplicity of information. Overcoming any design flaws in these features assists users in achieving successful and overall gratifying experiences. Well-structured information architecture helps features on the UIs to be more findable: by organising information and features in a clear manner, allowing for the least amount of confusion, a short learning curve for users, and making it easy for users to find what they are searching for (Maassen, 2008).

All UIs should be accessible, to enable users with disabilities to access features or allow users to access the UIs from different devices (Arhippainen & Tahti, 2003; Morville, 2004; Maassen, 2008). If UIs are designed with ease of use and accessibility in mind, regardless of the user's ability, more users will gravitate towards these designs. An example of a UI being accessible to users with disabilities is to have a feature that could talk to users that are visually impaired.

The models depicted in, Figure 3.3 and Figure 3.4, differ in that Morville's (2004) model (Figure 3.3) has two extra elements that have an effect on UX. To make a UI credible it is vital to have an interface that looks good displaying a particular style or branding, as well as information available regarding legal matters, privacy protection, and security. If these properties are not addressed, people will not want to use the UI (Morville, 2004). The branding of the product is out of the scope of this research, however, it is helpful to note all influencing elements that affect UX. UX does not only focus on people using devices and what they look like, but rather what value is delivered to the users during this process of interaction, notably, customer satisfaction or monetary rewards or reputation (valuable). The value created through the interaction with a user is highly important as this will have a positive or negative affect on the UX. When all the elements are taken in their entirety and altered in a way that positively influences users' attitudes towards UIs, the UX is likely to be a positive one.

The contextual factors relate to all influences at a particular time and place, such as using public transport, at home or in a business meeting late at night. How users experience the MUI is dependent on their surroundings (Arhippainen & Tahti, 2003). All experiences are subjective and can never truly be predicted; therefore, approaching the UID in a comprehensive manner will enable part of the MUX to become predictable as many design elements try to overcome the problems that most users face with them.

3.2.1 Mobile User Experience

Mobile user experience (MUX) incorporates all the components related to UX but is specifically linked to a user experience with a mobile device (Law *et al*., 2009; Nielsen & Norman, 2013). A closer look into the interaction between users and mobile user interfaces (MUIs) can help to understand factors that may affect the overall MUX (Law *et al*., 2009). UX is a very broad term that describes all interaction between a user and a product within certain conditions (Law *et al*., 2009; Nielsen & Norman, 2013). Similarly, mobile user experience (MUX) is any experience a user has while operating a mobile device in varying conditions (Arhippainen & Tahti, 2003; Ballard, 2007).

3.3 Human Computer Interaction

Human computer interaction (HCI) is the study of how people interact with computers (technological devices) and to what extent computer devices are, or are not, developed for successful interaction with human beings (Love, 2005; Carroll, 2013). One of the main intentions of HCI and mobile human computer interaction (MHCI) is to understand the users, their various capabilities and expectations, and how these can be taken into consideration when designing applications for technological devices (Love, 2005). UX and MUX refer to the whole experience of the user with the product, whereas HCI is only the interaction of the user with the product (Hassenzahl & Tractinsky, 2006). Hence, HCI relates to the design, evaluation, and implementation of interacting computing devices for human use (Hewett *et al*., cited in York & Pendharkar, 2004; Carroll, 2013).

3.3.1 Mobile Human Computer Interaction

MHCI is an extension of HCI in that it pertains particularly to the study of how people interact with mobile devices on a daily basis (Love, 2005). MHCI is one of the general components that affect the MUX as well as the MUI. Users interact with mobile devices through an interface, and the usability of the interface has an effect on how users perceive that MUI as well as MHCI, ultimately affecting the MUX (Love, 2005; Chincholle *et al*., 2013). The usability of the MUI is a term that is used in MHCI to describe the properties products need to possess, for example,

efficiency of use or ease of learning, in order for users to enjoy the mobile device (Nielsen, 1993). All components of MHCI have an effect (positive or negative) on MUX and thus these factors need to be considered when designing how users experience mobile devices (Love, 2005; Viljamaa & Vaittinen, 2007; Chincholle *et al*., 2013).

Emphasis is always placed on the users when designing MUIs. An understanding of the environment in which users are using the technology (context of use) is also important as this can have a significant impact on their ability to interact with the MUI in an efficient, effective, and satisfying way (Love, 2005).

An important characteristic of MHCI is that different users formulate different mental models or perceptions about their interactions and have various ways of learning and retaining knowledge and skills (Love, 2005). Cultural and national differences also play a part in how people interact with MUIs. In addition, rapidly changing technology provides new interaction possibilities to which users may not know how to react, however, user preferences and opinions change as they gradually master new interfaces (Rouse, 2005).

The basic goal of MHCI is to improve the interactions between users and MUIs by making the mobile devices more usable and receptive to users' needs (Bevan, 2001; Chincholle *et al*., 2013). Designing a usable UI allows users to have more efficient use of their MUI which becomes easier to learn how to use, and results in a more satisfying and successful MUX (Bevan, 2001). Usability encompasses the attributes that make a UI usable; it also refers to the quality and efficiency of a device in supporting the user to reach certain goals or perform certain tasks (Quesenbery, 2001).

MUIs present MHCI designers with the following challenges: designing for mobility, designing for a widespread population, designing for limited input/output facilities, and designing for users multitasking at various levels (Dunlop & Brewster, 2002; Heo *et al*., 2009). Users that have mobile devices will often have no props (e.g. table) around them to support their activities, and they will complete their tasks on mobile devices in environments that change significantly as users move. Users in the widespread population do not have formal training with their MUIs, therefore functionality must be intuitive (Dunlop & Brewster, 2002). The screen size of mobile devices have limited input and output facilities, even though the screen sizes have improved in colour depth and pixel resolution, they will always need to be 'small' due to the need for portability (Dunlop & Brewster, 2002; Knoche & McCarthy, 2005). Mobile device systems need

to support multitasking and task interruption as the opportunities for, and frequency of, interruption are likely to be higher given the changing environments MUIs are used in. To many people, the usage of mobile devices does not necessarily suggest being on the move but represents a means of communication that is ready at hand (Knoche & McCarthy, 2005). An understanding of the difficulties that MUIs and environments bring to MHCI can assist in an enhanced UID which ultimately affects the MUX.

3.3.2 Usability Principles

The following principles are pertinent to good design and usability and they form the basis on which MUIs can be evaluated. Together their outcome will affect usability and ultimately the MUX. Usability is mainly a characteristic of the user interface, but is also associated with the functionalities of the product and the process to design it. It describes how well a product can be used for its intended purpose by the targeted users (Bevan, 2001).

Nielsen (1993) proposes a set of usability principles showing usability as a multi-dimensional component divided into five usability metrics (Figure 3.5) namely: learnability, memorability, errors, efficiency, and satisfaction (Nielsen, 1993).

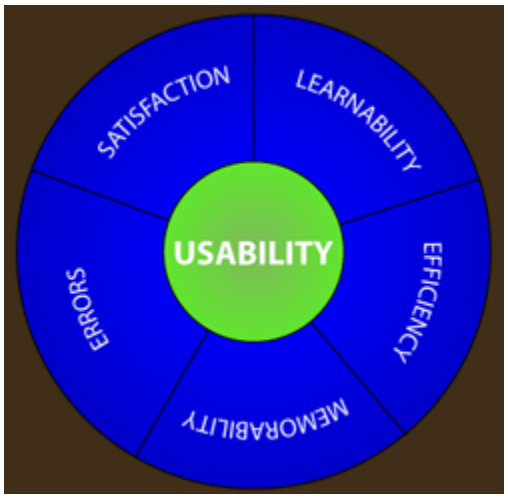


Figure 3.5: Usability Principles (Nielsen, 1993)

- Learnability: The system should be easy to learn so users can promptly begin work on the tasks they wish to complete.
- Efficiency: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible and the user becomes more effective in their use of the system.

- Memorability: The system should be easy to remember, so the user is able to return to the system after some time of not having used it, without having to re-learn how to use it again.
- Errors: The system should have a low error rate, so that users hardly make errors during the use of the system, and if they do make errors then they can recover from them. Catastrophic errors must not occur as this affects the usability of the system.
- Satisfaction: The system should be enjoyable and pleasant to use, so that users are satisfied when using it and they like the system.

ISO 9241-11 (1998) provides a standard and guidance for usability. The standard states that usability deals with the degree to which a device can be used by users to achieve their goals with effectiveness (task completion by users), efficiency (task in time), and satisfaction (user's ultimate experience and satisfaction), within a specified context of use (tasks, users, environments and equipment). If mobile device UIs are able to encompass all of these factors, users are more likely to find the devices usable, resulting in a better MUX (Love, 2005). Nielsen's principles and the ISO 9241-11 standard are comparable. The difference is that Nielsen specifies principles of learnability, memorability, and errors which can be grouped under the ISO standard of effectiveness. The ISO standard also differs from Nielsen's principles in that it includes the context of use as a factor affecting usability, which is highly important as mobile device users have ever changing contexts of use.

The above factors that affect MUX as well as the five usability attributes are regarded to be of high importance when designing usable UIs. They should be taken into account along with the components discussed next, to enable an overall understanding of what improves the usability of UIs, in particular touchscreen MUIs, and enhances the MUX for users.

3.4 Mobile User Interface Design

Mobile user interface design (MUID) is the design of mobile devices with the focus on the user's experience and interaction (Van Greunen, 2009). The MUI is how the user will interact with a mobile device and this may have an effect on the MHCI since this involves the interaction and usability of the mobile device (Van Greunen, 2009). As a result of this interaction, the overall MUX may be affected.

Heo *et al.* (2009) describe a model, which is based on usability factors affecting mobile phones. The model consists of four sets of checklists including one for task-based evaluation and three

types of user interface (UI) checklists (Figure 3.6). Heo *et al.* (2009) separated the logical, physical, and graphical user interfaces and described what type of elements may be contained in each. Similarly, the task-based checklist was created and includes the criteria that should be observed, and adhered to, when using MUIs to complete tasks.

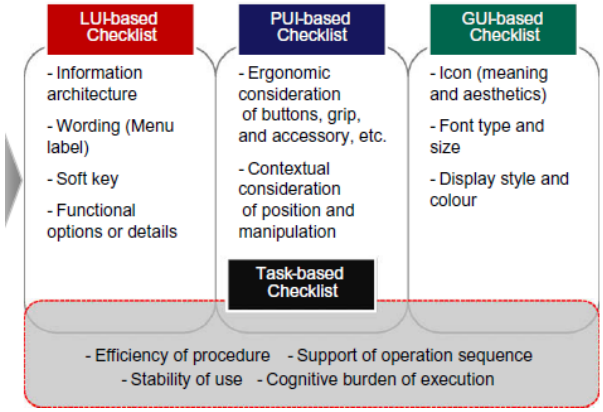


Figure 3.6: Evaluation Strategy (Heo *et al.*, 2009)

The physical user interface (PUI) comprises of touchable components that users operate in order to carry out tasks. These include: ergonomic understanding of the buttons, grip, touchscreen, and overall size of the device, as well as the contextual consideration of position and manipulation of the mobile device (Heo *et al.*, 2009). The logical user interface (LUI) refers to the organisation of the information architecture, wording (menu labels), functional details, and the structure of information (navigation) in order to complete tasks, for example, the layout of titles and operation sequence (Heo *et al.*, 2009). The graphical user interface (GUI) comprises visual items (look and feel) that display information such as: different font types and sizes, display style and colour, and icons that have different meanings and aesthetics (Heo *et al.*, 2009). The visually appealing components of the mobile devices together with the logical and physical elements help users to complete their tasks. The task-based checklist is useful to find out usability problems during the task completion process and generate design options that can promise better task performance (Heo *et al.*, 2009).

This model is used as a means to structure this research and evaluate the usability of the PUI, LUI and GUI, in order to better perform tasks using the various interface components and understand how best to make them more usable (Heo *et al.*, 2009). This model, in particular, was used to help the researcher find usability problems easily and produce better design solutions for the problem space (Heo *et al.*, 2009). The model follows a simple arrangement (LUI, GUI and PUI) that makes logical sense for this research and helps to group information into readable and relatable chunks so that it can be used to create a set of usable user interface design guidelines

for VRCs. The PUI, LUI and GUI form the overarching structure in this chapter and classify which components should be included within the interfaces (Heo *et al.,* 2009). One interface category can have properties relating to two or three interfaces at the same time, such as LUI (menu) and GUI (fonts, icons and colour).

3.5 Physical User Interface

PUI refers to the tangible, physical interface properties such as the battery, touchscreen, tangible buttons, and labels to name a few, that support the physical controls needed to carry out tasks (Ham *et al*., 2006). The PUI domain consists of the grip, buttons, and all components that the user can touch and handle in a physical way. All the mobile devices discussed in this research are assumed to be touchscreen smartphones. Understanding the physical characteristics of touchscreen smartphones enables the researcher to gain a better understanding of the PUI users interact with and how the characteristics of smartphones may affect the overall MUX.

Touchscreen smartphones have a distinctive electronic visual display that enables the screen of the phone to detect/sense any movement on it and operates according to the movement. Users operate the touch (haptic) action using their fingers or thumbs (Park & Han, 2010). Touchscreen smartphones are relatively slim as well as smooth and sleek. Users interact with touchscreens through the interface where generally no other input devices are needed (Pirker, Bernhaupt & Mirlacher, 2010). Users directly manipulate the touchscreen graphical user interfaces (GUI) also known as the MUI, where input and output take place at the same time, making the UI very intuitive to interact with (Waloszek, 2000; Pirker *et al*., 2010).

A PUI that is attractive and comfortable, that allows users to operate the MUI more easily, can help increase the usability and user satisfaction (Heo *et al*., 2009). An appropriate PUI design enables users to perform more accurately thus increasing the simplicity of the MUI, and ultimately the usability.

Feedback presented to users must be given more than once to be understood correctly, this can be done using tactile feedback or in the form of colour, shape, text or sound (Wickens *et al*., 2004; Shneiderman & Plaisant, 2009). Norman (1988) advocated audio, tactile, and visual feedback to indicate to users what action was done and what result was accomplished. Similarly, Subramanya and Yi (2007) suggested that interfaces should give visual and auditory feedback to show users that the system has responded to their selections.

Users should be kept aware and informed through suitable feedback and within reasonable time in order to help users' efficiently complete tasks, as suggested by Nielsen (1993) and Ji *et al*. (2006). The response rate of the touchscreen UIs (moving between screens) should be to one hundred milliseconds or less in order for users to feel that the system is reacting instantaneously. Tactile feedback is important on MUIs, particularly in the case of button occlusion (user's fingers block the screen information from line of sight), as it is used to regain some of the feeling lost when interacting with a touchscreen smartphone, since feedback is more difficult to sense than with physical buttons (Hoggan, Brewster & Johnston, 2008; Pirker *et al*., 2010). Physical buttons have an engraved surface so users can feel what they are selecting, whereas virtual buttons have no physically detectable space between adjacent buttons (Kwon, Lee & Chung, 2009). The virtual icon/button must include a suitable button depression or sound to inform the users that the button press actions have been successful. Any sounds or feedback vibrations should however be easily switched off (Roto & Oulasvirta, 2005; Stockbridge & Mughal, 2007). When a system is busy processing a request that takes longer than four seconds it is important to provide additional feedback (haptic or sound); similarly, if the system is unable to respond to button presses, it becomes important to provide a moving icon that reassures users that the system has not crashed (Stockbridge & Mughal, 2007). The user has no control over the system's feedback speed, however, it is important to give users timeous feedback when the system takes longer than usual to respond.

The inclusion of dynamic feedback for touchscreen interaction directly influences the usability of icons and buttons, for example, an icon that has been touched contains an associated sound for quick feedback, and this reduces the chance of double tapping by the user (Huang & Lai, 2008). If the flashing effect or aural feedback of the icon is unstable or insensitive, users may face problems. The delayed feedback to users can cause serious issues which makes users frustrated and compels them to tap the icons (buttons) too many times, causing the system to malfunction (Huang & Lai, 2008). In a study by Hoggan *et al*. (2008), tactile feedback was added to a touchscreen device. The results showed that this feedback significantly improved finger based text entry, allowing users to effectively interact with MUIs, improving their performance and reducing users' error rates.

In the PUI domain there is interaction between the MUI and the user through direct manipulation, exchange of information, and feedback (Heo *et al*., 2009). Feedback can be given to the user through sound, graphics or physical cues (Shneiderman & Plaisant, 2009). All physical or audible feedback relates to the PUI components of the device, however visual

feedback can be given through the GUIs. Although the PUI is acknowledged as a factor affecting the MUI of a product and ultimately the MUX, it forms a limited part of this research since the physical nature of touchscreen smartphones is beyond the control of the researcher. The LUI and GUI elements are focused on in this research because they can be altered by the researcher whereas the PUI, to an extent, is physically unchangeable. The main component of PUI that will be considered in this research is haptic feedback.

3.6 Logical User Interface

The LUI is defined as the interface related to information architecture, navigation structure (wording and menu labels), and findability (the ability to find information and functional options) in the MUI (Heo *et al*., 2009). The LUI comprises the following sections: information architecture and navigation, and wording. These components are supported by many authors' works and grounded in principles specified by Norman (1988), Nielsen (1993), Tognazzini (2007), and Shneiderman and Plaisant (2009).

3.6.1 Information Architecture and Navigation

Information architecture (IA) is a technique to design clear, understandable interactions by focusing on structure, presentation of data, context and information (Corkins, 2012). Users are more likely to understand how to search through and use the information on the MUI of a smartphone if it has a consistent structure and flow (Nielsen, 1993).

The inclusion of quick access shortcuts for frequently used features, clear screen titles for easy, efficient orientation within the menu structure, and menu options grouped in a way that users expect, will assist in making smartphone UIs more usable (Norman, 1988; Ji *et al*., 2006). Users should be able to navigate easily through the well organised and coherent UI layout, and should be able to find things they are looking for quickly, as well as learn how to use the system with ease.

Navigation is the way users gain access to certain features in the MUIs, using various routes (Botha, 2011). Klockar *et al*. (2003) considered mobile phone usability, with a focus on features, size of the screen, and the layout of navigation keys. They found that users could perform tasks using frequently-used features without any problems, however, when users were asked to perform infrequent activities they found it difficult to navigate the mobile phone menu system. Thus, placing most frequently used features first on menu lists helps to speed up navigation and improve the operation sequence of users and the features they access (Klockar *et* al., 2003).

Navigation through the IA should not be a cumbersome task and should require minimal effort that allows users to find what they are looking for easily (Venkatesh, Ramesh & Massey, 2003).

Information that is displayed as lists should attempt to ease the stress placed on user's memory and balance between the users' knowledge and knowledge in the world must be sought after for an effective MUID (Nielsen, 1993; Shneiderman & Plaisant, 2009). Depth and breadth are two key characteristics that need to be considered if a hierarchical structure (menu) is used, as navigation problems occur when a hierarchy grows deeper (Papp & Cooke cited in Chae & Kim, 2004). The advantage of depth in a menu structure is that it encourages funnelling (reduction in the total number of options a user must choose among), and the disadvantage is that it induces errors and increases the number of screen transactions (Andersson & Isaksson, 2007). The advantage of breadth is that it reduces navigation errors and the number of screen transactions; however, the disadvantage is that it leads to crowding (brought about by excessive breadth). Users' short-term memory can typically retain 7 ± 2 items, thus no more than nine items per menu structure should be used as this overloads users' short-term memories and they lose track of what they have searched for (Papp & Cooke cited in Chae & Kim, 2004). The concept of recognition rather than recall should be used to minimize user's memory load by making objects, actions, and options visible (Nielsen, 1993). The users should not have to remember information from one part of the system to another; therefore the UIs should be kept simple (Nielsen, 1993; Shneiderman & Plaisant, 2009). The balance of depth and breadth affects both the navigation behaviours and user preferences of MUIs. Simple menu labels and icons should be used to support better usability and to allow easy navigation between screens and options (Nielsen, 1993; Venkatesh *et al*., 2003; Ji *et al*., 2006). Similarly, Klockar *et al*. (2003) suggested that phone usability could be greatly increased by incorporating thorough menu design and careful attention to navigation design. Real-world conventions (metaphors) should be followed to make information emerge in a natural and logical order, matching the system with the real world, to help make navigation through menus straightforward (Norman, 1988; Nielsen, 1993; Tognazzini, 2007).

The options provided for navigation should be the most likely next step for the user, and should include an 'undo', 'back' or 'cancel' option for every screen, so the user does not feel trapped at any time (Stockbridge & Mughal, 2007; Tognazzini, 2007). Similarly, Nielsen (1993) advocates user control and freedom of navigation by supporting undo and redo to allow users to escape from an unwanted state. Unchanging visual elements or perceptual cues allow users to navigate quickly through screens and all actions should be reversible (Nielsen, 1993; Tognazzini, 2007;

Shneiderman & Plaisant, 2009). A historical navigation for previously viewed pages and a quick access route back to the main screen will allow users to establish where they are in the system and how to navigate back to a familiar screen (Stockbridge & Mughal, 2007; Tognazzini, 2007). Graphical elements (back buttons) are needed for navigation through MUIs, in order to make the user flow logical and efficient.

3.6.2 Wording

The use of consistent and familiar terminologies, clear and simple menu labels, and well-defined screen titles will allow users to easily orientate themselves through the menu structures and help them to understand what each item can achieve (Nielsen, 1993; Stockbridge & Mughal, 2007; Shneiderman & Plaisant, 2009). The familiarity of the terms used may help to increase the learnability as well as efficiency of users (Tognazzini, 2007). Menu and button labels should have the key word(s) first, for example, page break instead of insert page break (Tognazzini, 2007). The quality of the semantics used in ideograms (an icon with accompanying words) allows for more effective usability of the MUI, as well as determines whether information has been conveyed properly; this is shown by whether it has been used correctly by users (Huang & Lai, 2008). Technical jargon must be avoided as not all users will understand the terms. Language must also be considered as the MUI may have to cater for different languages that do not have direct translations for the words used (Ketola & Röykkee, 2001; Stockbridge & Mughal, 2007).

The wording that is chosen for a UI can impact on how users experience and use the MUI depending on the users' cultural and social differences. The selection of specific words to label menu items and any other type of information should be a well thought-out process (Stockbridge & Mughal, 2007). The system should speak the user's language with words, phrases, and concepts familiar to the user, rather than system-oriented terms (Nielsen, 1993). McDonald and Schvaneveldt (cited in Chae & Kim, 2004) discovered the way in which menus are labelled and categorised has a significant influence on user behaviour and perception. Paap and Cooke (cited in Klockar *et al*., 2003) also agree that word choice is of particular importance as any menu item must include all items underneath it and simultaneously exclude all items found elsewhere in the menu.

One of the advantages of touchscreen smartphones is that error messages are rarely needed since direct manipulation and immediate responses (feedback) take place on screen; however, should an error occur, the UI should clearly give users feedback regarding what error has occurred

(system feedback) and constructively suggest how to resolve it (Stockbridge & Mughal, 2007; Pirker *et al*., 2010). The error message should be expressed in plain language with no technical jargon until dismissed by the user to allow for sufficient reading time (Nielsen, 1993; Shneiderman & Plaisant, 2009). Error-prone conditions should be eliminated or checked and presented to users (Nielsen, 1993).

3.7 Graphical User Interface

GUI is concerned with graphical or visual features presenting information which users need to make use of to perform tasks, for example, icons/buttons (meaning and aesthetics), font type and size, as well as the display style and colour (Heo *et al*., 2009). The GUI components are supported by many authors' works and grounded in principles specified by Norman (1988), Nielsen (1993), Tognazzini (2007), and Shneiderman and Plaisant (2009).

3.7.1 Buttons and Icons

An icon is a visual representation of something on a device, for example, a phonebook icon (Galitz, 2007). A button on a smartphone combines the icon (image) and text relating to the image to create a clickable area that users can press to perform tasks. Icons are essentially buttons with images and are thus interchangeable terms (Galitz, 2007). Icons and buttons are fundamental features of the GUI and make interacting with a UI more user-friendly, since users do not have to enter text commands each time they wish to accomplish a task (Galitz, 2007). When designing icons, an understanding of users' mental models (the models users have of themselves, things they interact with, and other people) should be used to create visual items that convey a greater purpose than just a pretty picture (Nielsen, 1993; Tognazzini, 2007; Nielsen, 2011). Similarly, Klockar *et al*. (2003) suggests that designers should pay careful attention to users' mental models and the conceptual models of the system. The conceptual model refers to the actual model displayed to users through the MUI. These models use visual components such as mappings, constraints, and affordances (Weinschenk, 2011). Mappings are the relationship between features and their influences on the system. Constraints are the restrictions imposed on users during their interaction with the interface and its features. Affordances are the perceptual cues that buttons encompass that inform the users on how to use them (Norman, 1988). Users combine the conceptual models of the system with their own mental models and through their interaction with the UI they interpret its apparent visible structures and actions (Norman, 1988).

Aesthetics are used to present task relevant information that is visually pleasing and useful to users completing tasks on UIs (Nielsen, 1993; Tognazzini, 2007). Users prefer icons on main

menus over the use of text labels, provided they clearly communicate their content and all graphical messages provide some user benefit so not to take up limited screen space (Stockbridge & Mughal, 2007). Interface metaphors exploit knowledge that users already have (mental models) from other areas, to give them instantaneous knowledge about how to interact with the UI (Nielsen, 1993; Tognazzini, 2007). Icons and interface metaphors are designed similarly to physical entities but also include their own properties, for example, a desktop metaphor or mail icon (Tognazzini, 2007). Metaphors enable users to instantly grasp the finest details of the conceptual model and create visible images in their minds. It cannot be assumed that all users understand the metaphors and icons used, however, using metaphors and icons consistently as seen in most MUIs should increase the chances of users understanding the image and message being portrayed. To decrease the chances of confusion for users, it is vital that discriminable icons are used when their functionalities are different (Tognazzini, 2007).

Icon metaphors such as documents, the rubbish bin, and folders can be: heard, seen, touched, and perceived. The seen icons are the most familiar in GUIs whereas touch (haptic) or audible icons are less familiar. Icons have an ordinary way of interacting with a standard resulting behaviour that should be understandable, stable, and consistent (Tognazzini, 2007). The icons help users to operate the UI more easily by presenting an environment with familiar objects that facilitate task completion (Galitz, 2007). Icons are very important in any GUI irrespective of the type of interface. Touch icon design improves users' performance and significantly reduces faults (Huang & Lai, 2008). The use of familiar metaphors helps to increase the memorability and learnability of the UI as well as the efficiency and satisfaction since users are familiar with the UI.

3.7.2 Buttons Shape and Size

Users interacting with smartphone technology directly touch the buttons on the screen with their fingers and addition of haptic (touch and force) feedback for touched buttons allows for a faster, efficient, more accurate performance to be produced in comparison to a mouse-controlled interface (Huang & Lai, 2008). The touch field is considered to be the size, location, space, and density of a button. Lindberg *et al*. (cited in Huang & Lai, 2008) state that button (icon) spacing, size, and location influences human visual search when users view graphic interfaces which directly affect the usability. These features all improve the 'tactility' of buttons for a more usable UI (Huang & Lai, 2008).

Buttons come in various shapes and sizes. Users prefer uncomplicated and simple buttons that allow them to complete tasks more easily (Venkatesh *et al*., 2003; Huang & Lai, 2008). Often buttons are accompanied by words and as mentioned earlier it is important that the words (semantics) used convey the correct message the icon is portraying (Stockbridge & Mughal, 2007; Huang & Lai, 2008).

Fitts's Law states that the time to acquire a target is a function of the distance to, and size of, the target (Fitts, 1954). Park and Han (2010) studied touch key (button) design for one handed thumb interaction and found that the button sizes for touchscreens should be between 7mm and 10mm for the best possible performance. Karlson and Bederson (2008) similarly expressed that icons smaller than 10mm result in high error rates when accessed with the thumb, due to finger occlusion. Large buttons should be used for important features to allow users to easily attain their intended targets (Karlson & Bederson, 2008). The amount of time it takes for users to hit the correct buttons will increase if the buttons are small and closely spaced together (especially with large fingers) (Tognazzini, 2007; Huang & Lai, 2008). Users need to concentrate their attention and slow down their actions in order to hit the correct buttons which reduces their usability (Tognazzini, 2007; Huang & Lai, 2008). On smartphones it is important to take into consideration the size of male and female fingers when creating buttons. Since female fingers are generally smaller than male fingers, the design of the screen style may need to be adapted according to the user, and cater for large fingers (Waloszek, 2000; Shneiderman & Plaisant, 2009; Pirker *et al*., 2010).

The location and sizes of buttons affects the usability of a smartphone UIs specifically for one handed interaction (Park & Han, 2010). The left area of the interface is most suitable for the smallest buttons, with the centre and the right areas being more suitable to bigger buttons (Park & Han, 2010). All frequently used buttons should be placed in the centre as they will be much faster to reach whereas buttons located in the lower right areas have poorer usability as there may be interference with the palm of the hand (Huang & Lai, 2008; Park & Han, 2010).

3.7.3 Fonts

Fonts refer to a particular typeface of a certain style and size, for example, a font could be Times New Roman 14 point bold (Galitz, 2007). All font considerations for menus and applications must adjust according to the screen size of the mobile device, or use a large font size (Chae & Kim, 2004; Pan & Ryu, 2009). The presentation of any text should be clear with contrasted shades between text and the background to ensure legibility (Wickens *et al*., 2004; Stockbridge

& Mughal, 2007; Tognazzini, 2007). The type and size of the font is integral to the legibility of text for users, for example, users with impaired vision may need the option to make the text size larger (Stockbridge & Mughal, 2007; Tognazzini, 2007). The case size of text cannot however be lowered below a point that is legible to users (Chae & Kim, 2004; Kiljander, 2004).

3.7.4 Screen Display

The screen display or UI style involves pop-up menus, main-menus, vertical/horizontal positioning of the screen, lists, and whether they are appropriate UI styles for the information being conveyed (Stockbridge & Mughal, 2007; Heo *et al*., 2009). The creation of a beautiful UI may lead to an enjoyable experience, however, it will not guarantee a usable MUI (Fadeyev, 2009). A structured menu, well-defined menu labels, and icon labels can make the presentation of information more understandable and easier to access (Stockbridge & Mughal, 2007).

The UI style should be consistent to assist users to easily learn how to use features from screen to screen, orient themselves as to where they are in a menu, as well as inform them of which tasks they can complete (Lindholm, Keinonen, & Kiljander, 2003; Roto, 2006; Stockbridge & Mughal, 2007). The UI style should be kept simple to reduce users' short term memory loads (Shneiderman & Plaisant, 2009). Users should not be trapped into a single path but rather well-marked 'signposts' should be used to assist with easy navigation (Nielsen, 1993; Tognazzini, 2007).

Currently, most if not all smartphones use colour to convey information that associates itself with positive or negative connotations and the colour 'attraction' is an important principle of usability, when users operate touchscreens (Huang & Lai, 2008). The colours are used to make buttons and UIs more attractive and can display status changes to users (Tognazzini, 2007; Huang & Lai, 2008). The colour red may appear attractive (positive connotation) or alarming (negative connotation) whereas blue icons may appear refreshing (positive connotation) or aloof (negative connotation). Although colour distinctions are useful for the majority of the population, about 8 % of males and 0.4% of females have red-green colour blindness, and only 0.01% of all humans suffer from blue-yellow colour blindness (Tognazzini, 2007). This indicates that smartphone UIs should not depend solely on colour distinctions to display changes but rather use brightness, redundant signals, location, and shape to enable colour deficient users to operate the system with ease and to change settings if need be (Tognazzini, 2007; Huang & Lai, 2008).

UI layout is a vital part of a user's navigation through a smartphone UI. The input fields used, titles describing menu options, and the style of the UI used, may affect the usability of the MUI and the ultimate satisfaction of the user (Norman, 1988; Heo *et al*., 2009). Systems must attempt to anticipate users' wants and needs, bringing to users all the information and tools needed to complete tasks (Tognazzini, 2007). The task context (physical, social and temporal) should be considered since requirements of users may change according to their situations. Since smartphone buttons are dynamic and rendered graphically, they can appear or disappear depending on the interaction context (McGookin *et al.,* 2008).

The UI layout and navigation of the mobile device should be considered when implementing vertical scrolling. Vertical scrolling is shown by displaying half of the text of the next line or by using a hanging arrow (visual indicator) to imply there is more text to be read (Stockbridge & Mughal, 2007; Nilsson, 2009). Nielsen (2011) however suggests that touchscreen devices should utilise horizontal swipes since touchscreen smartphone users generally expect to horizontally swipe their way through a carousel, whereas desktop websites have guiding principles to avoid horizontal scrolling. The use of various visual cues (vertical scroll bars) for information presentation allows the UI to be more flexible and reduces the crowding of screens to make the text more readable to users, whereas horizontal swipes can be used for navigation and carousels (which rely on users' mental models of 'flipping' through a magazine) (Chae & Kim, 2004; Nilsson, 2009; Nielsen, 2011). Scroll bars can be used to handle crowded UIs when a virtual keyboard is displayed at the bottom of the screen for entering text. There is a need for an efficient keypad layout regarding the buttons in order to reduce the number of button presses and to allow users to complete their tasks effortlessly (Mittal & Sengupta, 2009).

Great UIs include: designs that use intuitive mapping, applicable features that are all made visible, essential actions that are clearly affordable (users know how to use the feature), unintended actions that are constrained, and prompt feedback from the users' actions (Norman, 1988).

The UI layout should follow the Gestalt Principles that relate to visual perception and how users organise visual elements into groups or unified wholes when certain principles are applied (Chang, Dooley & Tuovinen, 2002). A few of the Gestalt principles that should be noted are:

- Proximity: elements that are displayed closer together are grouped as one whole.
- Similarity: elements that have similar attributes are grouped together.

- Symmetry: the eye prefers greater symmetry.

Using natural mapping (the link between what users want to do and what is perceived possible) of buttons and icons allows users to perform tasks intuitively and take advantage of physical analogies and cultural standards for immediate understanding (Norman, 1988).

To support a smooth operation sequence the following can be applied: minimize the number of screens and button presses required for core tasks to avoid overcomplicating simple functionality; keep screens clear, consistent, and uncluttered with quick access and different navigation routes for various users to access features; and avoid many buttons too close together, particularly commonly used features (Venkatesh *et al*., 2003; Stockbridge & Mughal, 2007). Similarly, Tognazzini (2007) and Shneiderman and Plaisant (2009) agree that simple, consistent UI layouts that aid navigation should be used to improve the usability of MUIs. Unnecessary similar features should be removed and dissimilar features should be highlighted. To ensure an aesthetic and minimalist design, UIs should not contain information which is irrelevant or rarely needed. Every extra unit of information in a MUI competes with the relevant units of information and decreases their relative visibility (Nielsen, 1993). With the limited size of touchscreens the number of buttons and features must be reduced to those that matter the most to the smartphone user (Nielsen, 2011).

3.7.5 Consistency

Consistency is an important part of the PUI, LUI and GUI components and is mentioned by Norman (1988), Nielsen (1993), Tognazzini (2007), and Shneiderman and Plaisant (2009) to be a crucial constituent in designing usable UIs. Different levels of consistency are needed when creating a usable interface (Tognazzini, 2007). The interface must be consistent with the user behaviour, for example, the shortcut buttons should maintain their meanings. The invisible structures should be consistent, such that if the screens are resizable by pinching the UI, all screens should be resizable (Tognazzini, 2007). The appearance of buttons and icons must be precisely designed to allow for easy and consistent use by users. It is imperative to be visually inconsistent when objects (features) act differently (different behaviour) as it is equally important to be visually consistent when objects act the same (similar behaviour). The most important type of consistency is consistency of users' expectations (Tognazzini, 2007). Norman, Nielsen, Shneiderman and Plaisant echo this sentiment; consistency and standards should be utilised so users do not have to wonder whether different words, situations, or actions mean the same thing. Consistent platform conventions should be followed to increase the usability for users.

Conversely Grudin (1989) argues against user interface consistency. Grudin ascertains that a detailed knowledge of users' task context can identify or disregard some dimensions on which design should be consistent. Consistency is regarded as significant when linked to the frequency with which users perform an activity. Grudin considers consistency to be one goal often in conflict with other goals that are at times more important. This infers that consistency should not be used all the time. If knowledge about user tasks is absent, some form of consistency may be the best option. When a UI is designed for a device, built for a wide range of purposes and users, it becomes more difficult to get a meaningful understanding of the users' tasks. In this situation, it may make sense to adhere consistently to some interface choices to provide users with the benefits of easier learning and knowledge transfer.

3.8 Natural User Interface

The natural user interface (NUI) refers to the manner in which users interact with the GUI of smartphones which allows them to complete tasks. NUI forms part of MHCI as it is the way in which users interact with the other MUIs (PUI, LUI and GUI). A NUI is a user interface intended to reuse existing skills for interacting directly with content (Blake, 2012). Users are able to interact with NUIs by means of various input modalities, which include motion tracking, stylus, voice, gestures, and multi-touch (Blake, 2012). While NUIs have many input possibilities they remain more than just a way of inputting data or interacting with a device, NUIs are a new way of thinking about how users interact with content (Blake, 2012). The main focus of users when interacting with technological devices is to gain access to their data, perhaps learn from their information, and interact with content irrespective of the setting. Since special situations may call for a specific type of UI to be used, content remains the only shared factor between any random interface modality (Blake, 2012). NUI comprises interactions that are designed, reuse existing skills, and have direct interaction with content (Blake, 2012). This research makes use of NUI using touch (haptic) gestures on smartphones.

3.8.1 Definition of Natural

An interface is natural if it exploits skills that we have acquired through a lifetime of living in the world (Buxton, 2010; George & Blake, 2010). This definition connects the concept of natural with the notion of reusing existing skills, as it makes it explicit that skills are not just the instinctive capabilities we are born with. Natural means using intuitive abilities coupled with learned skills we have acquired through interacting with our natural environment in everyday life (Buxton, 2010; Blake, 2012).

3.8.2 Natural Interaction Guidelines

Blake (2012) created the following guidelines using his knowledge of natural interaction and human cognition that can be applied to any type of NUI irrespective of the input modality. The four guidelines are instant expertise, progressive learning, cognitive load, and direct interaction (Blake, 2012). Allow for instant expertise and design for interactions that reuse existing skills, for example, utilise domain skills specific to the type of users that use the MUI and simple skills that are inherent in all people (for example, pointing). The NUI should minimise the cognitive load for users as well as provide for a smooth progressive learning path from basic tasks to more advanced tasks. The interactions should be direct and high-frequency, giving users more feedback to create an engaging realistic experience that is appropriate to the context at the time (Blake, 2012).

Gestures are a type of natural interaction that can be used to interact with touchscreen technology (Saffer, 2008; Pirker *et al*., 2010). A gesture is any physical movement that a digital device can sense and respond to without the assistance of a traditional pointing apparatus, such as a stylus or a mouse. The gesture can be a head nod, toe-tap, a touch, or a raised eyebrow (Saffer, 2008). Gestures are non-contextual and can be performed anywhere in the system, in various locations, and at whatever time (George, 2009). The average TV users are more interested in what they are watching on TV rather than the technology they are interacting with, therefore the interaction must be as easy as possible (Lee *et al*., 2008).

The general types of touch/haptic gestures used in touchscreen technology are in the form of direct manipulation:

- A tap is used to select an item, for example, a button or an icon (Saffer, 2008).
- A pinch/spread (using thumb and index finger) increases or reduces the size of items shown on the screen by pushing the fingers apart and bringing them closer together.
- A swipe (slide) allows movement from right to left and left to right where menus or screens alter.
- A scroll (flick finger) is used in place of scrollbars or toolbars at the edges of the display, making it viable to use a touch gesture to move the screen up or down.
- A tap and hold of an item is generally used to display a set of ‘hidden’ options that the user can interact with, for example, a delete option.

The above gestures are considered to be performed through direct manipulation which occurs at a specific location on a specific object, with an immediate reaction taking place due to the direct correlation between the cause and effect of the interaction and UI (Blake, 2012).

3.8.3 Advantages of NUI

The advantages that NUI has over GUI for accomplishing general purpose tasks are: NUIs are more efficient and flexible than GUIs due to new input technologies being available (gesture control), whereas GUIs are confined and limited to a keyboard and a mouse; NUIs are simpler to learn than GUIs since they focus on more natural behaviours; and everyday tasks are easier to complete (Blake, 2012). GUIs and mouse-driven interfaces will still have a purpose in the future, however, that purpose or role will be for when GUIs are the most efficient way to complete a specialised task. The overall system for a device can be designed using a NUI since it is not about the input device, but rather the interaction style (that being natural) (Blake, 2012).

3.8.4 Good Gestural Interfaces

Good gestural interfaces should be discoverable and it must be obvious that users can interact with an interface by using affordances showing multiple indicators as to what actions can be taken (Saffer, 2008). The interface should be trustworthy, ensuring it appears competent and safe while being responsive to, and acknowledging, an action whenever possible and as rapidly as possible (100ms or less, to make the response feel instantaneous). The gestural interfaces should be appropriate to the situation, culture, and context they are in, as well as being meaningful, to meet the needs of the users that utilise it. The system should be smart and perform activities that we as humans do not remember and cannot easily do alone; as well as clever to predict the needs of the users and fulfil those needs in unexpectedly pleasing ways (Saffer, 2008). The interfaces should be playful, enabling users to play around with the functionality and explore as well as engage with the interface. All errors should be difficult to make so that warning messages do not have to be used all over the UI. Good and pleasurable interfaces should be created that are aesthetically and functionally pleasing to the users, and that show respect for the users (Saffer, 2008).

3.9 Conclusion

This chapter discussed the importance of understanding the factors that affect MUX (UX) which include: social factors, cultural factors, context of use, the user, and the product. The following questions should be asked when considering modifications to the MUI:

- Do users find the MUI useful?
- Is the MUI usable or easy to use?

- Do users find the MUI valuable?
- Is the MUI desirable and visually appealing?
- Are all features within the MUI findable?
- Can all users access all the features?

Once the factors affecting the MUX were established; the MHCI, as well as the usability principles that set the foundation for usable products, were discussed. The usability principles assist the researcher in measuring the usability of the MUI by understanding the: learnability, memorability, errors, efficiency, satisfaction, and effectiveness of the mobile device. The MUID was reviewed in terms of PUI, LUI, and GUI (Table 3.1). The NUI was also discussed as a natural way of interacting with touchscreen mobile devices which incorporates common touch gestures such as: tap, tap and hold, pinch, swipe, and scroll (Table 3.1).

The insight into the MHCI properties that touchscreen smartphone UIs should encompass and the factors that influence MUX, enables this research to focus on creating a successful and usable MUID that positively influences MUX. All the pertinent points from this chapter are documented in the table that follows and will be used to inform the set of user interface design guidelines for usable VRCs (Table 3.1).

Table 3.1: Proposed Guidelines for Physical, Logical, Graphical and Natural User Interfaces

PUI	References

Feedback:
Aural, visual or tactile feedback should be given to users
• To show that the system has responded to their actions e.g. button depressions
• More than once to be understood correctly
• Within reasonable time:
  o < 100ms instantly
  o If > 4sec give additional feedback e.g. moving icons
	(Norman, 1988; Nielsen, 1993; Waloszek, 2000; Wickens *et al*., 2004; Roto & Oulasvirta, 2005; Ji *et al*., 2006; Stockbridge & Mughal, 2007; Subramanya & Yi, 2007; Hoggan *et al*., 2008; Huang & Lai, 2008; Heo *et al*., 2009; Shneiderman & Plaisant, 2009)

LUI	**References**
Menus: Menus should be well-structured and well-grouped • Use the 7± 2 rule for menu items • Well-defined menu and icon labels • Frequently used items first on the menu list **Wording:** Provide users with familiar, non-technical language (wording) • Clear and simple UI titles • Consistent wording • Avoid technical jargon	(Norman, 1988; Nielsen, 1993; Ketola & Röykkee, 2001; Klockar *et al*., 2003; Paap & Cooke cited in Klockar *et al*., 2003; Venkatesh *et al*., 2003; McDonald & Schvaneveldt cited in Chae & Kim, 2004; Papp & Cooke cited in Chae & Kim, 2004; Ji *et al*., 2006; Stockbridge & Mughal, 2007; Tognazzini, 2007; Huang & Lai, 2008; Shneiderman & Plaisant, 2009)

• Use correct semantics for words accompanying buttons (icons) • Label the key word first for labels and menu items	
Error messages give users information about what went wrong	
• State which error occurred and give constructive help • Use plain language with no technical jargon • Allow for sufficient reading time	
Navigation:	
Navigation must follow a consistent structure and flow that allows users to explore the interface	
• Simple navigation that is not cumbersome • Real-world conventions/metaphors to allow the information to be logical and natural • Use recognition rather than recall to limit stress placed on users memory • Include undo, back or cancel buttons for easy reversal of actions • Provide quick access (shortcuts) to frequently used features e.g. home button • Provide unchanging visual cues • Use historical navigation for previously viewed pages	
GUI	**References**
Mental Models:	(Norman, 1988; Grudin, 1989; Nielsen, 1993; Chang *et al*., 2002; Venkatesh *et al*., 2003; Lindholm *et al*., 2003; Chae & Kim, 2004; Kiljander, 2004; Wickens *et al*., 2004; Roto, 2006; Tognazzini, 2007; Stockbridge & Mughal, 2007; Huang & Lai, 2008; Karlson & Bederson, 2008; Lindberg *et al*., cited in Huang & Lai, 2008; Heo *et al*., 2009; Nilsson, 2009; Mittal & Sengupta, 2009; Shneiderman & Plaisant, 2009; Park & Han, 2010; Nielsen, 2011; Weinschenk, 2011)
Features and functionality should be aligned with user mental models	
• Use icons for menu items where possible • Use metaphors to help users instantly understand processes • Use metaphors consistently	
Buttons:	
Buttons (icons) should clearly communicate the content they represent	
• Button sizes between 7mm and 10mm • Use large buttons for important features • Use uncomplicated, simple buttons • Use colours and appealing designs to make buttons more attractive	
Button placement and positioning should be consistent	
• Use good spacing between buttons • Left position on screen for smaller buttons • Right position on screen is more suitable to buttons • Frequently used buttons should be placed in the centre • Lower right areas on screen are harder to reach	
Screen Display:	
The user interface screen display should be kept simple, consistent and uncluttered	
• Utilise contrasting colours for text to improve legibility • Include a readable typeface and large font size • Make use of brightness, redundant signals, location and shape, to help colour deficient users • Give good default designs for a single coherent experience • Ensure correct input objects are used, for example a dropdown • Include prominent 'signposts' that assist users with easy navigation • Provide visual cues for scroll bars • Use a combination of horizontal swipes and vertical scrolling for	

navigation	
Graphical Principles: Consistent graphical principles and grouping should be applied	
• Minimise the number of screens and button presses	

• Consistency should be employed throughout the GUI
  ○ Through user behaviour
  ○ Invisible structures
  ○ Be visually inconsistent when features are different
  ○ Be visually consistent when features are the same
  ○ Predicting user expectations	

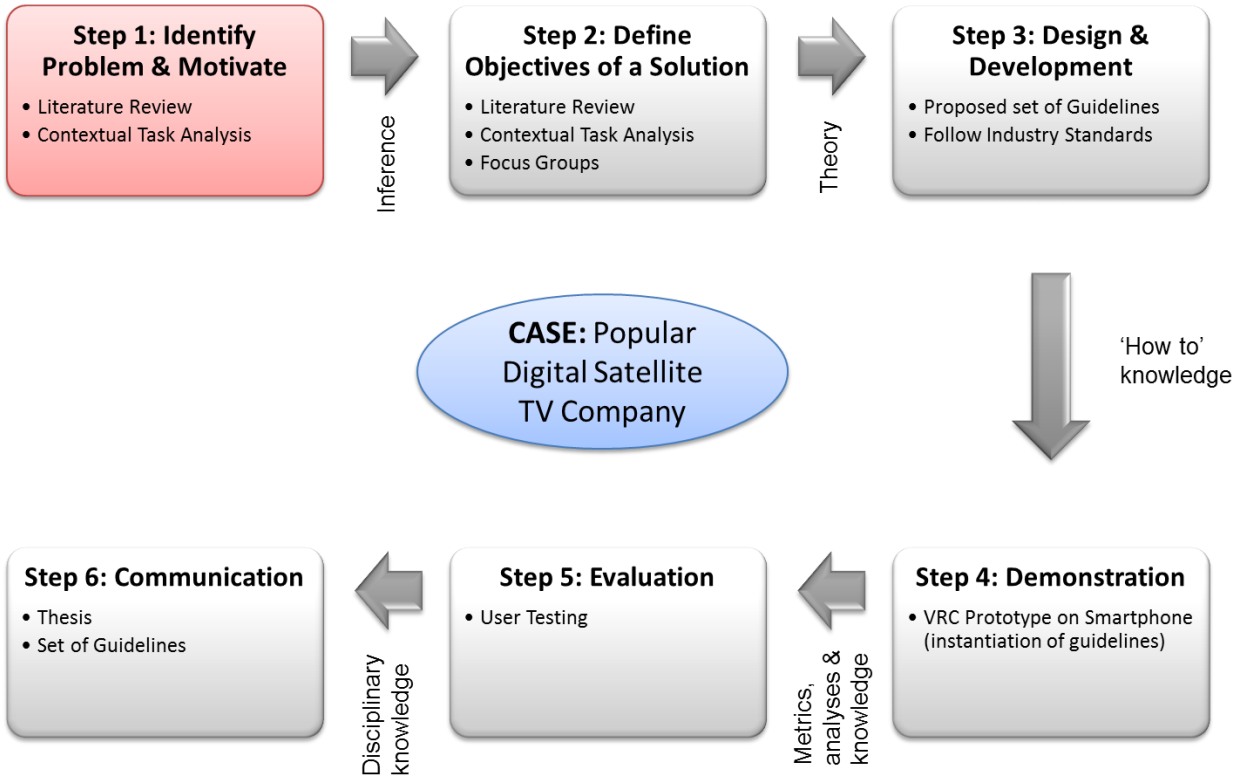
• Elements displayed closer together are grouped as one whole	
• Elements that have similar attributes are grouped together	
• Users prefer greater symmetry	

NUI	References
Gestural Interfaces: Gestures used should be natural actions that users are familiar with in order to increase their interaction	(Saffer, 2008; George, 2009; Buxton, 2010; George & Blake, 2010; Pirker *et al*., 2010; Blake, 2012)
• Use multiple indicators to show what actions can be taken	
• Rapid instant responses to touch	
• Appropriate gestures for different situations, for example tap, tap and hold, pinch, swipe, and scroll	
• Use playful engaging gestures that allow for exploration of the system	

Chapter 4 Remote Control Usability

4.1 Introduction

Chapter 4 contributes to step 1 of the DSRP model which relates to the problem identification and motivation for the research. This is completed through a review of the literature pertaining to the usability of remote controls.



The purpose of this chapter is to highlight current usability issues of physical remote controls (PRCs) and virtual remote controls (VRCs). Remote controls are used to interact with various appliances in different environments. In household contexts PRCs are the most commonly used interaction devices. A PRC is defined in this literature as a control device that has physical properties, buttons, and labels that have a set layout and cannot be altered (Ament, 2007). A VRC as defined in this literature is a remote controlling device that uses computer-generated graphics on a screen to display the buttons and icons (functionality) available to users to operate and control a device (Sony Ericsson Mobile Communications AB, 2005). This chapter discusses the usability of TV PRC physical properties, such as the number of buttons and colours used, as well as the usability of the elements that comprise VRCs, such as labels, layout, navigation, and visual style. This chapter answers the second research sub-question, "*What are the current usability issues with physical and virtual remote controls?*"

4.2 Physical Remote Control Usability

This research examines the usability pros and cons for PRCs, with particular focus on TV remote controls. PRCs have physical buttons that users press to control devices, such as TVs. PRCs typically send one-way commands from the user's PRC to devices in order to perform tasks that involve changing channels or switching the devices on/off (Sweetser, Grunnet-Jepsen & Panchanathan, 2008). An infrared receiver on the appliance picks up the signal from the remote control and verifies, from an address code sent, that it must carry out a specific command (Layton, 2011). The following subsections pertain to buttons since this is the primary way in which users interact with, and use, to control the PRCs.

4.2.1 Number of Buttons

PRCs have evolved from the first PRC in 1952 which contained less than ten buttons to PRCs that now include upwards of forty buttons and have become more complex with various layouts that allow for more tasks to be completed. The excessive buttons make for awkward, confusing, and unnatural interactions when performing 'advanced' actions, such as searching for TV programmes (Berglund *et al*., 2006).

Usability problems exist with PRCs when they contain a vast number of button choices, which creates confusion and frustration for users (Cooper, 2008). The number of buttons available is fixed according to the physical layout of the PRC (Figure 4.1) and cannot be adapted to suit the user (Hess *et al*., 2008; Wang *et al*., 2009). PRC users generally limit their selection to a small set of buttons that are regularly used, for example, the channel up and down buttons (Berglund *et al*., 2006; Cooper, 2008). However, to overcome the limitation of fixed buttons new types of interaction technologies, such as touchscreen interfaces, can be employed to allow access to a broad range of features (Wang *et al*., 2009).

Figure 4.1: Physical Remote Controls. A) Tivo Remote (Hafner, 2004); B) Apple Remote Control (Cooper, 2008: Apple 2015); C) Sky Remote Control (Sky, 2015).

The numerous buttons that PRCs have increases the complexity of PRCs and ultimately decreases the usability (Nielsen, 2004; Darnell, 2008). This is because infrequently used buttons negatively impact usage of PRCs by utilising space that could be used to make commonly-used buttons bigger and easier to select (Omojokun *et al*., 2006). PRCs typically have all the buttons users might desire for any interaction. The issue is that users often complete a small set of tasks with their PRCs, typically not needing all functionality their PRCs provide (Omojokun *et al*., 2006). As a result, incorporating fewer features into PRCs translates to: fewer buttons, less risk of hitting the incorrect buttons, less complexity, and an increase in the probability that users will understand the remaining features (buttons) and find them useful (Nielsen, 2004; Darnell, 2008). An example of fewer buttons on a PRC is shown in Figure 4.1-B (Apple, 2015). Komine *et al*. (2007) similarly expressed that to make PRC UIs more usable it is vital to have as few buttons as possible in order to lessen users' mental barriers in the initial stage of usage. Berglund *et al*. (2006) and Lee *et al*. (2008) echo this point saying that the increased number of buttons displayed on PRCs increases the complexity of the user's mental model. If the interfaces are confusing and too complex, users will struggle to use the PRCs appropriately and these issues will hinder the objective of keeping PRC interfaces simple and easy to use (Nichols & Myers, 2003). It is crucial that technological devices in home environments are usable and viewers are in relaxed settings making it important that UIs assist the users in their interactions with devices (Bernhaupt *et al*., 2008). Resolving these problems will involve the development of simple and easy to use interfaces that integrate existing ways of how people use and interact with PRCs (Berglund *et al*., 2006; Hess *et al*., 2008).

An example of a PRC that has less than 35 buttons is shown in Figure 4.1-A. The PRC is comfortable for long periods of in-hand use. It has a medium curve 'peanut' shape and a simple button layout. Each button has a distinctive feel giving users the ability to control the remote without looking at it (Hafner, 2004). Similarly the Sky remote control Figure 4.1-C is regarded within the industry as an excellent PRC since it has limited the amount of buttons on the PRC to 38. It is well-designed and has suitably placed buttons that allow it to be used without looking at the buttons (Cooper, 2008).

While the reduction of the number of buttons has attempted to decrease the complexity of the PRC, it still has fixed functionality and is unable to be personalised according to users' everyday needs and according to the buttons (features) they commonly use (Hafner, 2004). PRCs relate only to the device they control and not the user that is operating it, suggesting that users have to deal with many PRCs whose buttons are unable to be personalised or customised to users' needs, styles and abilities (Hilbert & Trevor, 2004). PRCs lack scalability meaning new buttons cannot be added to the interface and their physical structure cannot be changed without being replaced by new PRC parts. Thus, PRCs are not flexible enough to adapt to changes in interaction.

4.2.2 Shortcuts

Many PRCs have dedicated shortcut buttons that are associated with certain features which improve the speed of interaction with the device, for example, the buttons for 'TV guide', 'services' 'menu', and 'interactive', as shown in Figure 4.1 A, B and C (Cooper, 2008). Dedicated shortcut buttons can be very convenient for users once they learn what each button does as they provide quick access to main features. PRCs cannot provide every channel with a dedicated shortcut button to directly access that channel since this would require hundreds of buttons to be available on the PRC, making it difficult to use (Pirker *et al*., 2010). Pirker *et al.* (2010) expressed that users would find it difficult to use a PRC if it contained hundreds of buttons since the broad variety of functionality would make it more complicated and confusing to interact with.

4.2.3 Button Size and Shape

The buttons on TV PRCs generally have ways to navigate through menus, change channels, adjust the volume, and turn the device on and off. The buttons are mapped on the PRC and are rather small which makes the PRC more difficult to operate (Cesar *et al*., 2008). The small buttons that are narrowly spaced can make PRCs more difficult to use and ease of use of a PRC is one of the most important requirements when interacting with TV (Berglund *et al*., 2006).

Lessiter *et al*. (2008) investigated the usage of PRCs with a group of adults over the age of 75 that had a range of impairments. They typically faced problems with the unclear and uniform button layouts as well as identical shaped buttons with similar sizes. These features were the most difficult to use since older users had to try identify each button's functionality. The user group found PRCs easier to use when they had larger handsets with varied button sizes, shapes, designs, layouts, and height (Lessiter *et al*., 2008). Lessiter *et al*. (2008) found that varied button shapes and sizes for PRCs worked best (as is evident on Tivo remotes, Figure 4.1-A).

Darnell (2008) investigated the usage of a digital TV system by less technically-inclined people as well as more technically-inclined users, and found that participants had issues with the various PRCs as they all had different styles and modes that were inconsistent, therefore choosing the correct PRC became a challenge. The PRCs are often similar colours, shapes, and sizes making it difficult to select the desired one in a dark room (Nielsen, 2004). PRCs have many inconsistencies in their UIs, for example, the placement of the on/off button is either at the upper left position, upper right position, or in the middle position of the PRC. Users tend to press other buttons instead of the button they usually press in that position, causing frustration amongst users (Nielsen, 2004).

Some remote control developers have used differently shaped buttons rather than colour buttons to represent the fixed features on PRCs, as displayed in the Tivo and Sky remote controls. Figure 4.1 A and C (Cooper, 2008; Apple, 2015). Basic geometric shapes such as squares, circles, stars, and triangles can be used, since unlike colour buttons there is no possibility of confusion in the case of low light conditions or colour blindness. In addition, shaped buttons themselves can be distinguished through touch alone since users get immediate tactile feedback from them (Cooper, 2008). Myers (2004) observed that a few physical buttons on PRCs were often used without looking, for example, the volume and channels. This showed that once users were well practised with using PRCs that they relied merely on tactile feedback to navigate options on the TV. Tactile feedback (physical) thus plays an important role in PRC (Cooper, 2008).

4.2.4 Colours

The benefit of having colour buttons on PRCs is that they are visually separate from alphanumeric and numeric buttons, as is evident in Figure 4.1 A and C (Hafner, 2004; Cooper, 2008; Sky, 2015). The problem is that colours are inconsistently used in PRCs, for example, different buttons and labels have different colours and these colours do not have significant and meaningful connections to the features they are allocated to (Cooper, 2008). The meaningless

association of colours to features does not allow users to relate different colours with specific features to help create useful mental models. The colour association between PRC buttons and different features is largely random and inconsistently applied, as shown in Figure 4.1-C, which can cause usability problems. For example, a red button on a PRC can delete items in interactive TV however the same button can also be used for other purposes while watching TV (Cooper, 2008). A limited number of colours used to represent an open set of possible options on PRCs make it difficult for users to associate the use of a particular colour with a specific feature in a given context. Users may, however, learn certain combinations through frequent use; nevertheless, the association is easily broken (Cooper, 2008).

4.2.5 Labels

The plethora of buttons directly relates to the labels since most buttons have labels associated with them. The labels on PRCs are often confusing as users do not always understand the meaning of the chosen words, for example, FL dimmer. Unclear button label choices decreases the usability of PRCs (Nielsen, 2004; Carmichael *et al*., 2006). The complex labelling of buttons creates confusion amongst users as to what purpose certain buttons have, and thus better labelling is needed to improve the usability of PRCs (Nielsen, 2004). Users that are technically inclined may understand these labels however the usability of the labelled buttons is reduced when taking into account the array of ambiguous choices. Users attempt to create a simple mental model with their understandings of the PRC and the labels associated with the buttons. Ninety percent of buttons are clearly labelled however the ten percent of buttons, that have complex and unclear labels, hamper the mental model users try to create thereby affecting their experience of the PRC and their ability to understand what each button does (Nielsen, 2004).

The terminology used for labels should be intuitive, standardised, and easy to read (Cooper, 2008; Wang *et al*. 2009). Good contrast should be used between the buttons, labels, and background colour (Figure 4.1-B), as well as large sized fonts to make the labels legible (Carmichael *et al*., 2006; Tiresias, 2009). The labels should be durable and not rub off since users may forget what purpose the buttons served (Carmichael *et al*., 2006; Tiresias, 2009).

4.2.6 Navigation

PRCs are designed with various navigation systems and menus which can be accessed through button presses. PRCs therefore, have different buttons for retrieving different menus and all the while users are required to observe the information displayed on the TV screen, as well as search for related buttons and labels on the PRC, thereby focusing on two devices simultaneously (Berglund *et al*., 2006; Pirker *et al*., 2010). PRC navigation of TV menus can be a clumsy and

laborious task when using the up/down/right/left buttons in conjunction with watching a movie. For this reason it is vital to provide shallow or simple menu structures where a small number of PRC buttons can directly select frequently-used features without any menu navigation (Cooper, 2008). Frequently used features should be mapped so they are directly accessible via the PRC, helping to reduce the menu navigation burden on viewers, as shown in Figure 4.1-A. Mapping between navigation buttons on PRCs and TV menus should be clear (Költringer *et al*., 2005). Each menu item should be selectable sequentially with only one navigation key and all navigation operations should be reversible. Users have problems navigating through TV menus with PRCs that do not apply these principles (Költringer *et al*., 2005). Approximately 77% of TV viewers hold the PRC in one hand and press the buttons with a thumb, implying that PRCs should support 'thumb navigation' (Eronen, 2003).

The navigation systems (menus) should be based on simple lists of items that users can navigate through (Cooper, 2008). To reduce menu navigation problems for viewers the most important features on PRCs should be mapped to colour buttons and the TV screen features should correspond to the colour 'code' to reinforce the colour association (Lee *et al*., 2008). Some PRCs enable users to determine the level of interface sophistication and give them power over the advanced features by the amount of times they press a particular button. An example of this 'spiral approach' is that for each feature, a pressed button invokes the most basic and simplest form of the feature. Pressing the same button a second time presents a more sophisticated and advanced form of the same feature. The more times a button is pressed the more advanced the features become. The 'spiral approach' allows a passive viewer to settle on the most basic features without being exposed to possibly confusing, more advanced features. Those users who wish for more control and power over their interactivity can do so by pressing the same button repeatedly (Lee *et al*., 2008).

4.2.7 Reversible Actions

PRCs usually have a clear exit button and it is important that they give users an easy method of cancelling an action or returning to a previous location since users have difficulty trying to exit back to the TV from recordings and 'locked' channels, making them feel trapped in the actions they have selected (Cooper, 2008; Darnell, 2008). Giving users the ability to exit functions quickly and reverse their actions easily encourages them to explore features they might have been hesitant to select (Cooper, 2008).

4.2.8 Text Entry

PRCs are not always suitable for text input (Berglund *et al*., 2006; Hess *et al*., 2008). PRCs are ill-designed for complex interaction like entering text (multi-tapping) to search for content. The alphanumeric buttons are mapped to characters to support text input and they have to be pressed numerous times in order to find the correct letter (Cesar *et al*., 2008). The multi-tapping text entry method is evident on Figure 4.1-C; the buttons have numbers and letters on them. Entering text using a PRC has been problematic. A virtual keyboard on the TV screen as well as an SMS (short messaging system) text messaging style have been suggested, however, the research community agrees that cumbersome text input with PRCs should be avoided if possible (Lee *et al*., 2008). Numeric keypad layouts are also inconsistently used in PRCs. A guideline that can be used is a standard numeric (telephone) layout for numbers, in order to overcome these inconsistencies, as shown in Figure 4.1 A and C (Nielsen, 2004).

4.3 Virtual Remote Control Usability

Users face challenges with VRCs since they are new ways in which to remotely control devices and users are accustomed to existing input devices i.e. PRCs that have physical buttons (Pan & Ryu, 2009). Such users need some time to get used to VRCs and some learning might be needed to operate them correctly. Figure 4.2: Virtual Remote Controls. A) Remote for Samsung TV (Google Play, 2014); B) Decoder PVR Remote (Google Play, 2014).

shows two examples of VRCs that are available to the public.

A B

Figure 4.2: Virtual Remote Controls. A) Remote for Samsung TV (Google Play, 2014); B) Decoder PVR Remote (Google Play, 2014).

Pirker *et al*. (2010) investigated the problems associated with the introduction of touchscreen interaction in a living room and found that one quarter of participants did not take much time to learn how to use the VRC and they found the VRC pleasant to handle. Pirker *et al*. also found that although PRCs are easier to use, with time and practise touchscreen interaction can become easier to use. Conversely Nielsen (cited in Pirker *et al.*, 2010) suggests that users are likely not to bother with devices that require additional learning time since people prefer to stick to what they know and users merely want to start getting things done instead of spending 'unproductive' time learning. PRCs are what people are used to and new interaction techniques, for example, VRCs, would require some training or 'getting used to' in order to make users feel more comfortable with the device (Pirker *et al*., 2010). The following section describes the user interface design considerations related to VRCs and their usability.

4.3.1 Button Size & Shape

Huang and Lai (2008) investigated users' expectations and experiences with different types of icons on touchscreen remote controlled home entertainment systems and found that the icon size strongly affects usability. If the icon/button size is too small the target essentially decreases and the likelihood of tapping the incorrect icon/button increases (Huang & Lai, 2008). On smartphones, icons are used to represent buttons and thus the words for the most part can be used interchangeably.

4.3.2 Labels

VRCs are able to display larger more descriptive labels and content by allowing features to be on separate screens due to the 'virtual' nature of the screens (Huang & Lai, 2008). This allows for more advanced features, which may require multiple steps, to be hidden on other screens, away from novice users so as not to confuse them, while still allowing expert users to use all functionalities (Nichols & Myers, 2003). Descriptive labels and menu items should be used to describe the general contents of the screens they lead to which allows users to easily navigate between screens, as is shown in Figure 4.2-B with the Guide button (Huang & Lai, 2008).

4.3.3 Feedback

VRCs are able to provide feedback capabilities that PRCs have not been able to provide, such as a second screen (apart from the TV screen that a user receives feedback on) for extra information, or use vibrations for notifications (Cesar *et al*., 2008). VRCs have their own display screens that enable visibility of buttons and features to be enhanced since the distance between the TV and the viewer is reduced (Lorenz *et al*., 2009).

Problems associated with virtual buttons on VRCs is that they lack the natural tactile feedback provided by physical buttons and users cannot sense/feel where the buttons are located while watching TV (Pan & Ryu, 2009; Pirker *et al*., 2010). In Figure 4.2 A and B, the VRCs are both intended for touchscreen smartphone devices which do not have any physical buttons. Users' hands obscure the UI during interaction and there is a lack of precision of human fingers (Albinsson & Zhai cited in Pirker *et al*., 2010). Other common faults are linked to precision problems with the touchscreens such as: problems with accuracy and speed of the VRC; accidental activation of a feature, for example, pressing OK instead of up and vice versa; and general usage issues such as unintentional mistakes due to the unfamiliar interaction techniques (Pirker *et al*., 2010).

Users operate touchscreen VRCs through the use of direct manipulation (touch interaction) which is a very familiar and natural way to interact with a device as it enables users to directly complete tasks with their hands/fingers, helping to make actions more intuitive (Pirker *et al*., 2010). Tactile feedback, in the form of vibrations, improves the usability of virtual buttons in terms of user performance, as well as leading to a more satisfying UX of VRCs (Koskinen *et al*., cited in Pirker *et al*., 2010). A heterogeneous group of users utilise VRCs in various contexts with varying preferences and it is important that the feedback is kept simple and can be customised for the users (Turunen *et al*., 2009; Pirker *et al*., 2010). For example, tactile feedback

can offer silent, non-visible feedback about certain features without disturbing users or overloading the UIs with graphic actions, thus saving space for other content.

4.3.4 Dynamic and Customisable

VRCs can overcome the current drawbacks of PRC interaction by allowing each viewer in the audience to have their own interactive VRC on a touchscreen device, without sharing one device amongst many viewers, as is the case with current PRCs (Roibás & Sala, 2004; Pirker *et al*., 2010). VRCs have integrated displays that allow for attractive and adaptable UIs to be built across different screens, thus allowing VRCs to be more flexible for users and enabling the content to be more legible (Roduner *et al*., 2007; Hess *et al*., 2008). Virtual buttons allow the UI to be dynamic and flexible which enables situation-dependent variations of button arrangements or visibility of specific buttons depending on the feature currently in use (Pirker *et al*., 2010).

Gill and Perera (2003) completed a consumer survey which indicated that TV viewers with 50 channels usually only use about 7 of the channels; users mentally customise their choices to exclude some channels in order to make scanning easier. This indicates that viewers are attracted to high functionality however they still require ease of use (Gill & Perera, 2003). Customisation allows users to specify their own arrangements of the display to suit their needs and be more useful to them, for example, expert users want more features to be shown whereas novice users want a simplified screen. A basic UI that encompasses all users' needs and most of their task requirements may help to improve the usability of VRCs and satisfy users' experiences (Gill & Perera, 2003). Since VRCs have digital screens that can vary according to the software used, users can change the appearances of the screens but still possess the same underlying functionality, making the devices (and applications) more user-friendly (Bernhaupt *et al*., 2008). There is no need to manufacture an entirely new PRC when new features are added for appliances since the software-based menus of VRCs can simply be updated, as is the case for Figure 4.2: Virtual Remote Controls. A) Remote for Samsung TV (Google Play, 2014); B) Decoder PVR Remote (Google Play, 2014).

A and B (Nichols & Myers, 2003; Pirker *et al*., 2010; Google Play, 2014). Touchscreen VRCs are able to be upgraded through wireless networks, to keep up to date with new changes to the features (Wang et al., 2009).

4.3.5 Layout and Navigation

Since VRCs placed on small touchscreen smartphones have a limited amount of screen space, icons and menus need to be strategically placed to utilise the limited screen size effectively (Pan & Ryu, 2009). Using functional grouping is important to construct good UIs. The groups must

delineate how features are placed in relation to each other and which features can be separated across multiple screens (Nichols & Myers, 2003). Figure 4.2-A shows the delineation of functionality by placing the numerical buttons in a group, and the other functionality below in a separate grouping.

4.3.6 Dual Screen

Touchscreen mobile devices consist of a screen that the various buttons and labels appear on. One of the major differences between PRCs and VRCs is that a VRC is on a touchscreen whereas PRCs have immovable physical buttons. Therefore, the two separate screens (VRC screen and TV) enable users to multitask and navigate between different screens and features on VRCs while keeping the TV screen unchanged; rather than having all the information on the TV screen or all on the PRC, for example, physical buttons and labels (Roibás & Sala, 2004, Cesar *et al*., 2008; Courtois & D'heer, 2012).

4.3.7 Visual Style

VRCs need to offer good usability to all user groups (Zimmermann *et al*., 2003). The VRC must be easy to use and easy to learn, with a well-designed look and feel to be able to compete with all PRCs in order to easily integrate with existing task scenarios and user understandings (Hess *et al*., 2008; Pirker *et al*., 2010). VRC functionality is not the only significant factor that influences users' experiences and choices, but rather style and appearance are important factors for creating better interactions and experiences (Csikszentmihalyi & Rochberg-Halton cited in Berglund *et al*., 2006). A well-designed interface must maintain a balance between a level of simplicity as more and more functionality is provided due to the advances in technology (Lee *et al*., 2008). Product design and the visual attractiveness of VRCs influence users' willingness to use devices, therefore great care must be taken in designing usable and appealing VRCs (Pirker *et al*., 2010).

4.4 Conclusion

This chapter discussed the usability and UX surrounding PRCs and VRCs and formulated a list of requirements based on the findings from the review of literature. The positive and negative usability aspects from PRCs and VRCs were extrapolated to provide a set of guidelines based on the findings that attempt to guide the audience to make more usable UI designs for VRCs in order to enhance the UX. The list of requirements (Table 4.1) will be used to supplement the set of user interface design guidelines for this research. The Heo *et al*. (2009) model that was used to structure Chapter 3 was also used to structure the following guidelines.

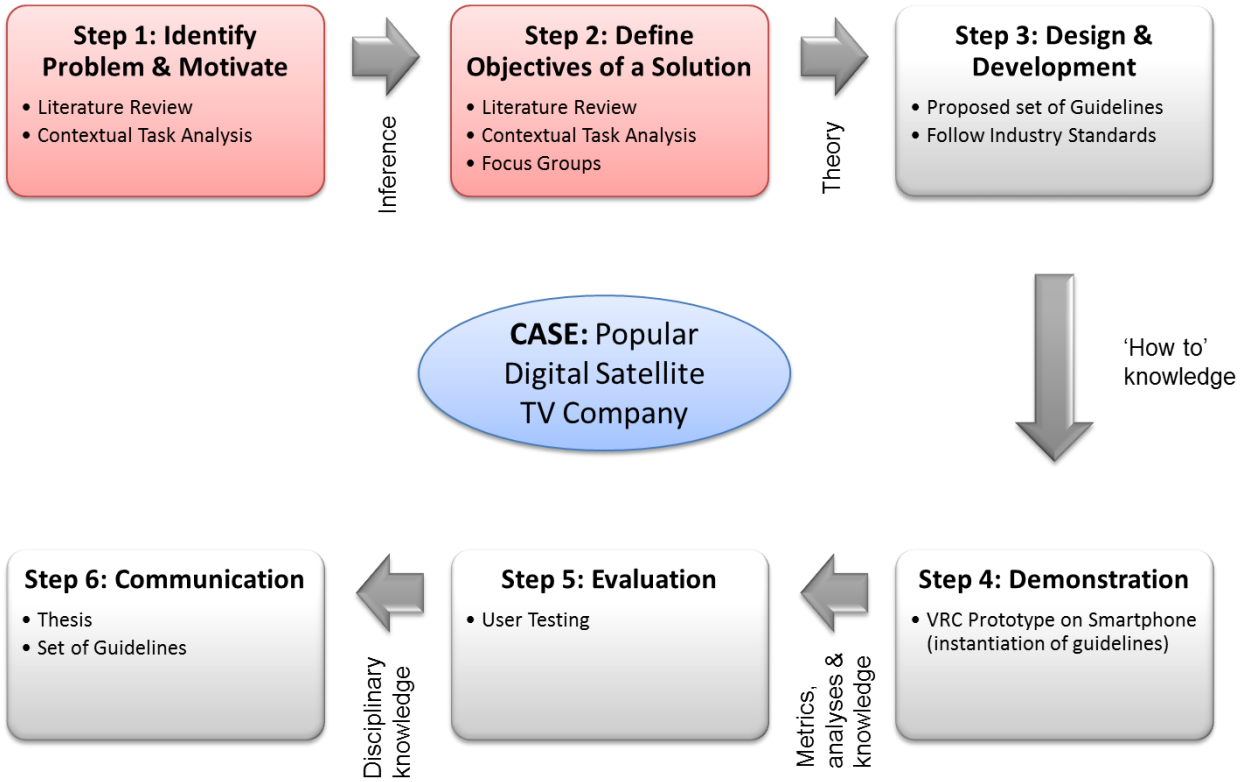
Table 4.1: List of Suggested Guidelines for Virtual Remote Controls based on Literature

PUI	References
Feedback: Immediate, tactile feedback should be given to users to make button selection more perceivable • Quick, immediate tactile, sound or visual feedback that can be customised.	(Cooper, 2008; Pan & Ryu, 2009; Turunen *et al*., 2009; Pirker *et al*., 2010)
LUI	**References**
Menus: Menus should be simple with shallow levels (hierarchical structures) for easy navigation	(Nielsen, 2004; Cooper, 2008; Darnell, 2008; Huang & Lai, 2008; Lee *et al*., 2008; Wang *et al*., 2009)
Wording: Make use of descriptive wording that is simple and clear to users	
Navigation: Navigation should be quick to access and allow users to explore the user interface • Place frequently used buttons in easy to access places • Use dedicated shortcut buttons for frequently used features • Use clear reversible actions (exit, cancel buttons) to enable users to explore interfaces	
GUI	**References**
Mental Models: Follow user mental models to correctly group functionality • Group buttons across different screens for situation dependent variables • Use the standard numeric (telephone) layout for numeric entry	(Eronen, 2003; Gill & Perera, 2003; Nichols & Myers, 2003; Zimmermann *et al*., 2003; Nielsen, 2004; Költringer *et al*., 2005; Berglund *et al*., 2006; Carmichael *et al*., 2006; Csikszentmihalyi & Rochberg-Halton cited in Berglund *et al*., 2006; Omojokun *et al*., 2006; Komine *et al*., 2007; Roduner *et al*., 2007; Bernhaupt *et al*., 2008; Cesar *et al*., 2008; Cooper, 2008; Darnell, 2008; Hess *et al*., 2008; Huang & Lai, 2008; Lee *et al*., 2008; Lessiter *et al*., 2008; Pan & Ryu, 2009; Tiresias, 2009; Wang *et al*., 2009; Pirker *et al*., 2010)
Buttons: Buttons should be placed in a manner that allows for easy access and quick thumb navigation • Keep the number of buttons to a minimum. • Use varied shape buttons, for example squares and circles. • Use large, clear and intuitive buttons. • Allow for sufficient spacing between buttons. • Hide or remove non-essential buttons from screens • Avoid cumbersome text entry methods. A quick and simple text entry method is needed.	
Screen Display: The screen display should be visually attractive and balance simplicity with functionality • Use a simple layout that is flexible to changes and updates • Design a stylish, intuitive UI layout that is easy to use and learn Contrasting colours and large font sizes should be used to improve legibility between labels and the background colour • Colours should be used consistently for buttons and labels. • Keep colours consistent with those in the real world, for example red for a power button • Ensure permanent labels are used • Large sized fonts should be used to make labels legible	
Graphical Principles: Place buttons in consistent positions • Clearly map buttons in positions conducive to their functionality • Use a consistent display style with consistent placement of buttons	

Chapter 5 Contextual Task Analysis

5.1 Introduction

Chapter 5 contributes to step 1 and step 2 of the DSRP model which relates to the problem identification and motivation as well as defining objectives of a solution for the research. This is completed through a contextual task analysis of users operating current digital TV PRCs.



The purpose of this chapter is to understand the context of use for users watching TV while operating PRCs, as well as identify the frequent tasks completed by users while operating PRCs, and understand what functionality currently supports users' activities or negatively affects the UX when operating PRCs. This chapter aims to give more insight into the PRC UI that users currently deal with and aims to better understand what improvements can be made, if any, or functionality that should be included in VRCs, so to make the UX more enjoyable. This chapter describes the contextual task analysis methods used to gather data about the context of use and tasks completed, and conclusions are drawn from those findings. This chapter aims to answer the second and third research sub-questions, "*What are the current usability issues with physical and virtual remote controls?*" and, "*What user interface design features should digital TV virtual remote controls contain?*"

5.2 Rationale for Technique

In this research, contextual task analysis (CTA) comprises a combination of contextual inquiry and task analysis. Contextual inquiry is defined as a field data-gathering, discovery technique used to assess carefully chosen participants in-depth to reach a fuller understanding of their real environments in which they operate products (Beyer & Holtzblatt cited in Kuniavsky, 2003; Usability Body of Knowledge [Usability-BoK], 2010). The natural/real environments were used in order to reveal users' needs, habits, and on-going behaviours within those environments, so to reduce the stress of being 'tested in a laboratory' and to give context to the research where the devices were used (Kuniavsky, 2003; Usability-BoK, 2010). This method helped to uncover what participants actually did in their natural environments and allowed the researcher to gain insight into the interactive processes surrounding the tasks of using a PRC. Task analysis provides a method by which to ensure that a system fully supports users and enables them to achieve their predetermined goals effectively and efficiently (Ainsworth & Marshall cited in Paradowski & Fletcher, 2004; Kujala, 2008). Task analysis aims to analyse what a participant is required to do in terms of actions and/or cognitive processes to achieve a task (Kirwin & Ainsworth, 1992; Kuniavsky, 2003; Kujala, 2008). Task analysis is closely associated with contextual inquiry, and data for the task analysis is collected during the contextual inquiry process. However the focus of task analysis is on the task itself (Wixon *et al*., 2002; Kuniavsky, 2003). Ideally, CTA should gather information from individual's in their natural environments in which they use the devices, in order to understand what tasks individuals complete, and how they complete them (Kuniavsky, 2003; Kujala, 2008). The researcher used CTA to gather the user needs and potential usability problems when using PRCs.

Mills (2000) and Cramer *et al*. (2004) utilised contextual inquiry to gain an understanding of the context of use for their systems to ensure all requirements and restrictions of the context of use were considered. Mills (2000) used usability context analysis and task analysis to assess the suitability of an Echosounder product for fishing (a simple mobile computing device with a straightforward user interface) by analysing the tasks users performed to achieve goals to understand their current use of the product, and discovered what the current limitations were of that product. The findings from Mills' (2000) research indicated the importance of task analysis and showed that it was necessary to analyse the tasks to a sufficient level that covered a range of similar working practices so the most suitable task sequences could be used to achieve particular goals. Cramer *et al*. (2004) showed that contextual inquiry can be a powerful way to inform the design of virtual reality applications by offering an understanding of the context of use. Although Cramer *et al*. found the contextual inquiry process to take considerable time and effort; carefully

studying users and context of use offered crucial information, namely the user needs and potential problems, for the development of the virtual reality applications. Similarly, this research uses contextual inquiry and task analysis methods to learn about the environments (context of use) in which people use their PRCs, the tasks they perform while using PRCs, and the problems and issues surrounding PRC usage.

Holtzblatt (2005) used contextual inquiry, during the contextual design process, to inform the designs of an mSports Baseball application for mobile platforms by interviewing and observing participants interacting with the products to understand their context of use of the products. Similarly, Kangas and Kinnunen (2005) used contextual inquiry early in their development process of the ImagePlus for a mobile phone to understand what users' current needs of the product were and to provide a real usage context, so that the data collected informed the product requirements. Spinhof and Calvi (2006) also used contextual inquiry methods to obtain insight into the users, their tasks, and their working environment of an interactive nursing terminal application, in order to develop a more user-friendly product that provided nurses with digital planning and patient information while out of the office. The above authors revealed to the researcher that contextual inquiry would be an appropriate technique to use to understand: the users' needs within their natural TV watching environments, the affect their surroundings have on their usage of the PRCs, and the way in which results can be interpreted for the design of the VRC smartphone applications.

The task analysis portion of the contextual inquiry attempts to inform the user interface design of the VRC; as proposed by Mills (2000) and Holtzblatt (2005), this research attempts to raise usability issues and identify tasks individuals perform and how they perform them, in order to understand their current use of the product, and to discover the current limitations of that product. Paternò and Mancini (2000) used task models (a collection of the user requirements based upon an informal task analysis) to identify the tasks a new interactive application containing museum information had to support. Paternò and Mancini endeavoured to find the problems associated with the application's performance in order to understand how to improve the system. Comparably, Paradowski and Fletcher (2004) made use of task analysis as a practical and efficient method to improve their graphical user interface of the fatigue modelling software's usability, user effectiveness, and satisfaction, by involving users in the process. Paradowski and Fletcher were able to identify areas of usability improvement and suggest alternate interface prototypes by means of the task analysis and user involvement.

Rose *et al*. (2005) used task analysis to focus on users of an electronic medical records system by observing individuals completing tasks with particular objectives, within their workspaces. Rose *et al*. asked participants to 'think aloud' in order to convey their thought processes while completing the tasks, and to offer feedback while interacting with the EMR system. The tasks were completed in the environment in which the EMR system would be used. This was done to understand what activities needed to be supported in a new design of the system, in order to identify the processes that did not work well and that needed to be re-designed (Rose *et al*., 2005). Looije, te Brake and Neerincx (2007) completed their study iteratively using a usability engineering methodology which consisted of three iterations, namely: user and task analysis, user testing, and focus groups. The first iteration which was relevant to this research focused on user requirements, the tasks users wanted the mobile maps application to support, and the functionalities users wanted in the proposed mobile maps application. The above authors demonstrated that task analysis is a useful technique that should be used to understand and identify the tasks users wish to complete. The task analysis can be completed using 'think aloud' methods to ensure users convey their thought processes, about the tasks, to the researcher. The researcher is able to understand problems the participants may have with completing tasks, using the system, and allows participants to suggest ways in which they would like to perform the tasks in order to improve their UX of the system.

The objectives of the CTA were:

- To understand common tasks that need to be effectively supported. This was performed to ensure that the frequent tasks are well supported in VRCs.
- To understand the usability issues in completing the common tasks. This was performed to identify the areas in which users may or may not struggle with PRCs, and to ensure that contextual environments and influences are all considered when creating the guidelines for VRCs.
- To give more insight into the PRC UI that users currently deal with to better understand what improvements can be made, if any, or functionality that should be included in VRCs.

5.3 Method

5.3.1 Participants

The sample for this research project includes members from the Grahamstown community in the Eastern Cape, as this population is the most accessible to this research project. The sample

focuses particularly on members of the public that subscribe to a popular digital satellite TV provider in South Africa. This research study will adopt a convenience sampling technique in which the sample is drawn from the part of the population that is close at hand (Tullis & Albert, 2008; StatTrek, 2011).

The age groups used in the study were based on the popular digital satellite TV provider's statistics. The age groups for the approximately 3.6 million subscribers have been divided into six categories as shown in Table 5.1 (Wentzel, 2011; Neethling, 2012). The 15-19 age group was not used for this research since part of the group of participants were minors. It was concluded that having at least two participants per age category (at least 1 participant in each category for the categories 50-60+) would represent convenient sample needed for the research.

Table 5.1: Population Sample (Wentzel, 2011)

Age Category	Representative base	Participants
15-19	12%	Out of scope
20-29	23%	2
30-39	23%	2
40-49	18%	2
50-59	12%	1 or more
60+	12%	1 or more

The participants for the CTA were chosen as a stratified sample of the target population shown above in Table 5.1. Two participants were chosen from each age category for the CTA. The various age categories were used in order to get a representative sample and more than one participant's feedback per age category, regarding their real-life TV viewing habits, the common tasks they completed, and any usability issues associated with completing those tasks. In total, ten participants (five males and five females) were chosen for the CTA. Due to the small sample sizes the results will not be statistically significant and cannot be generalised to the entire population (Tullis & Albert, 2008). Beyer and Holtzblatt (cited in Kuniavsky, 2003) suggested observing fifteen to twenty people while Kuniavsky (2003) considered fifteen to twenty people to be excessive due to the amount of interview and analysis time it required, and suggested that five to eight people gave a good idea of how a large portion of the target audience interacted with their products.

All participants that were chosen had been subscribers to the popular digital TV provider for at least six months, with the majority being subscribers for over 2 years (Figure 5.1-A). This ensured that participants had had time to get used to all the features and functionality of

controlling a digital TV decoder with a PRC. In addition, the majority of participants watched 2-4 hours of TV per day (Figure 5.1-B). Two of the participants were also familiar with personal video recording (PVR) functionality. PVR subscribers were able to access more features using the PRC, for example, the playlist with the list of recorded programmes, which were not available for non-PVR subscribers.

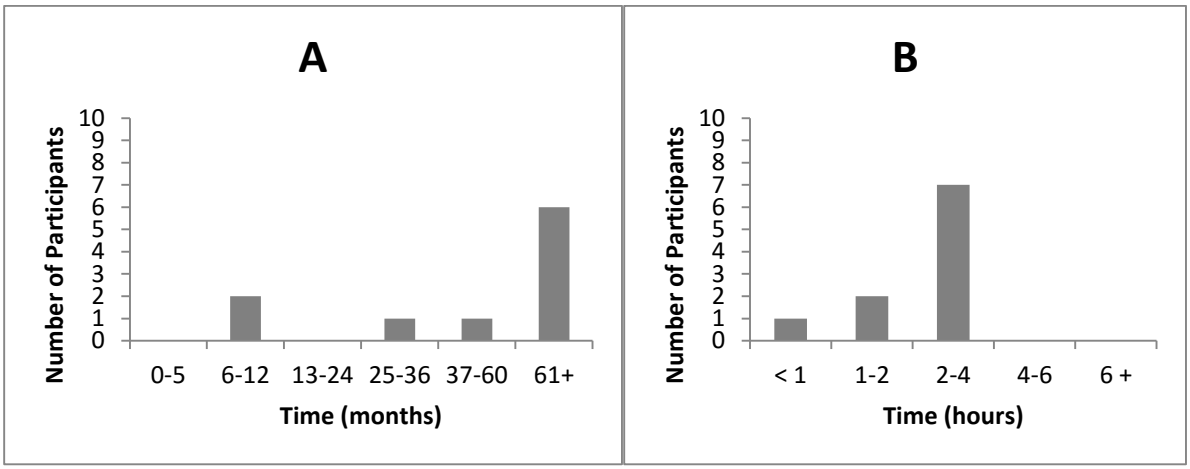


Figure 5.1: Participants. A) Subscriptions; B) TV Viewing

Only participants that agreed to the CTA taking place at their own homes were chosen for the study, in order to provide a natural environment for the process, as suggested by Kuniavsky (2003) and Usability-BoK (2010).

5.3.2 Procedures

Participants were scheduled separately to take part in the CTA on various days after work, during their typical TV viewing times. The process took a maximum of one hour to complete. Although some participants were from the same household their observations and questioning was performed separately. The reason participants were scheduled separately was to allow the researcher to observe and 'interview' them in-depth to gain more knowledge of the typical tasks participants completed when using the PRC, as suggested by Kuniavsky (2003). Video recorders were used to collect a diverse set of data from the interviews/observations of participants operating the PRC that included unique information about participant's natural environments, as well as the tasks they completed using the particular device. This data was collected in order to understand what problems participants faced when using PRCs and how PRCs were used to accomplish various tasks.

The master/apprentice role was explained to the participants (master). Participants were told to think aloud and narrate all of their tasks as if they were teaching the apprentice (researcher) about their tasks; all the while the apprentice could ask the master questions about key points. The master/apprentice role was used to get participants to explain and demonstrate how they interacted with and performed tasks using the PRCs. This allowed the researcher to focus on the details they may have missed if the participant had only explained the ideal situation (Beyer & Holtzblatt cited in Lazar *et al*., 2010; Usability-BoK, 2010). The role reversal may have been a difficult adjustment for the participants, however, the researcher encouraged the participants to fully explain what they were doing and encouraged them to inform the researcher about the goals (tasks) they were trying to complete (Usability-BoK, 2010). Participants were asked to provide a description of their typical habits when coming home and interacting with the TV using the PRC (general questions). They were probed as to what tasks they would generally do with the PRC and a list of the frequent tasks participants performed, were recorded. The less-frequent tasks that a few participants performed were also recorded to understand why the users may have struggled with the functionality, or did not know the functionality existed.

The main observation period was based on the frequent tasks participants were recorded to have performed using the PRC during the CTA. The tasks were explored further by the researcher through the master/apprentice roles. The researcher asked the participants to explain what buttons they were pressing, what they were trying to accomplish, and why they wanted to accomplish the task. The tasks participants demonstrated to the researcher varied according to each participant's CTA session. When participants had finished explaining how they completed each of the tasks, an in-depth discussion (follow-up interview) commenced. The researcher inquired as to what the participants found useful or problematic about current PRCs. The CTA was concluded by thanking the participants for their time and asking them if they had any other questions for the researcher.

Thematic analysis was used to identify, analyse, and report patterns (themes) found within the data collected during the CTA (Braun & Clarke, 2006). It was used to help organise and describe the data set in detail and interpret various aspects of the research topic, by combining the meaning of the analysis within their particular context (Kuniavsky, 2003; Loffe & Yardley, 2004). The participants and their individual contextual information were first considered followed by the tasks participants demonstrated during the CTA.

Each participant in the CTA was given a participant identity number (between one and ten) in order to conceal each participant's real identity. The data captured on the video recording device was transcribed and the notes taken during the CTA were studied to find the key focus points of each session to get an overall impression of the findings. This step was done in order to familiarise the researcher with the data, as suggested by Braun and Clarke (2006). A set of codes, or information that appeared interesting to the researcher was identified. The trends and themes were then extracted from all the notes and grouped together, and the various functionality participants mentioned was recorded (Table 5.3 and Table 5.7). The themes (segments) that were identified were reviewed in order to refine the initial findings to see which themes collapsed into each other, and which themes were not really themes. The themes were revised again to further define them and then they were reported upon (Braun & Clarke, 2006).

In this research a goal was something a participant wanted to accomplish and required one or more tasks to complete it using particular buttons and functionality (features) on the PRC (Table 5.3). The functionality referred to the actual buttons pressed by users to gain access to functionality on the TV. The tasks that participants demonstrated during the CTA were grouped together in order to understand how participants completed their goals. The functionality participants spoke about during the CTA was categorised into a table to get an overall idea of how participants operated particular buttons to complete their tasks and ultimately their goals. This data was used to inform the focus group sessions as a guideline as to which buttons and functionality were used most often by the participants and what the usability issues were. The salient points and subtle differences of each individual session were recorded separately and documented under each participant's identity number.

A hierarchical task analysis (HTA) was used to break the tasks down into sub-tasks and sub-sub-tasks as well as look for usability issues. The HTA was completed to better inform the prototyping phase so that the tasks with the least amount of steps and most used sub-tasks could be supported in the user interface design guidelines for VRCs (Hackos & Redish, 1998; Kuniavsky, 2003; Creswell, 2009). The results were discussed further in terms of their design implications to overcome any usability issues of the PRC and to inform the design of the VRC to allow users to successfully and efficiently complete their tasks.

5.4 Results

The results comprise definitions of terms used throughout these results (Table 5.2), the CTA, and HTA, as well as a summary of the features users found to be useful and problematic.

Table 5.2: Definitions of Terms used during CTA

Name	Description
TV Guide Button	a feature available on the PRC that when pressed a virtual TV guide appears on the TV screen with all the available channels, including times, dates and the names of programmes and can be navigated through using the arrow buttons.
TV Guide Magazine	a physical paper copy of the TV guide.
Channel	is assigned a particular number and if selected allows viewers to see what is being displayed currently and what will be showing next, for example the Home channel has one programme showing now and another one in an hour.
Programme	is the actual content that viewers watch, for example Colour Confidential is a programme on the Home Channel.
Channel Grid	is a table that shows all the channels on the TV screen and can be scrolled through using the PRC arrow buttons.
Alt Button	allows viewers to alternate/switch between two different channels, namely the channel the TV is currently on and another channel (the last channel the viewer was watching).
OK Button	allows viewers to select options that appear on the TV screen.
Banner Option	gives users the option to set a reminder for a programme on a particular day and at a particular time that appears on the TV screen by pressing the Ok button once when selecting a programme.
Auto-tune Option	gives users the choice to automatically change the channel from what is currently being viewed to another channel by pressing the Ok button twice.
Information Button	displays an information bar along the bottom of the TV screen showing what programme is currently on and what programme is on next.
Movie Renting Service	allows users to rent a movie on their TV for a set fee.
Shift	allows users to change between two different TV sets by pressing shift and selecting the TV which the viewer wishes to control, using the PRC (particularly for buttons that have dual functionality).
Audio	refers to the music channels available to viewers by pressing the shift button and then the audio option.
PVR (Personal Video Recorder)	allows users (PVR subscribers) to record programmes.
Catch-up	allows PVR users to access TV services showing a selection of series/shows/sports ready for users to watch.
Volume	controls the sound for the decoder.
Playlist	contains all the recorded programmes that PVR subscribers recorded.

5.4.1 Context of Use

All participants were asked to carry out their normal TV watching activities and their actions were observed and recorded. As the participants explained what they generally did whilst watching TV, the remarks they made were recorded, summarised, and are described in this section. The recorded data is broken up into sections, namely: the context of use, a summary of

the buttons used to operate certain functionality, a summary of the contextual environment, and the tasks that users performed based on their explanations of their typical TV watching activities.

Participant 1

Participant 1 first searched through the TV guide (virtual) looking at specific channels for something to watch. If the participant could not find something they then pressed the information button and scrolled through every channel. If there was an interesting programme on, the participant pressed Ok to select the channel but if there was nothing on Participant 1 turned the TV off and came back later to watch TV.

Participant 1 admitted to sticking to the channels they generally watched and found scrolling with the arrow buttons through the information bar the quickest way to find something to watch. Participant 1 said, "*I prefer to stay on what I am watching instead of going through the whole channel changing process.*"

Participant 1 particularly liked the banner option. "Y*ou have a choice with the banner whereas with auto-tune you do not have a choice.*" Participant 1 did not like the auto-tune as it "*cuts into the channel currently being watched and often there is not enough time to exit*". The participant did not like it when they accidently pressed the arrow button without being on the information bar and the channel grid popped up. They remarked, "*It does something strange and I don't know how to use the big grid. I don't like it, I thought it would be volume.*"

Participant 1 said that they would often pick up the PRC and carry it into the bedroom and then they would not be able to find it when it was needed. When using the PRC the participant said, "*I always look down when using the remote. I do not know it off by heart, I don't know the layout.*" Participant 1 had a new PRC but had noticed that on other friends' PRCs the labels had rubbed off, "*I would struggle to use it without the labels on it.*" The participant said they had never used the text function and said, "*I don't even know what it is for, don't think I would use it, I don't like the whole layout. I have lost touch with this type of layout*." The participant said that they would perhaps use the text feature it if it was a QWERTY keypad layout.

Participant 1 said that some of the buttons (arrows) were too small and would make them bigger, but the participant really liked the information button and enjoyed how the PRC fitted into the hand nicely, it had a "*good shape*".

Participant 2

Participant 2 turned on the TV and searched through their preferred channels to find something to watch. When Participant 2 searched for movies, the participant always read about them prior to watching movies and said, "A *preview would be a great option to have if you do not know what the movie is about… I often Google the movie to see what it is about and watch the previews online.*" Participant 2 never used the channel grid that showed all the channels saying they "*can't really watch the TV now at the same time; the channel grid blocks my vision.*" Participant 2 had never used the text feature and said, "*I never knew you could even enter text*".

The participant noted that the help button was in a good position on the PRC, but the participant did not use it often. Participant 2 generally knew where all the buttons were on the PRC and knew the layout well and hardly ever needed to look down at the PRC. The participant also had no problems with the size of the buttons even though the participant had large fingers.

Participant 3

Participant 3 would turn the TV on and automatically enter the numbers of a specific channel using the PRC to find a programme to watch. The participant would then use the information bar and arrows to scroll across, to find something to watch. The participant mentioned that in the evenings, whilst in bed, the participant would look for something to watch by using the catch-up list of series, or find a movie to watch by scrolling through the movie channels, or by using the movie renting service.

Participant 3 got irritated when having to scroll through all the channels especially those of which were not of interest to the participant. The participant wanted to limit the options to only the channels they preferred to watch. The participant was unaware of being able to setup favourites which included the channels the participant watched mostly. The participant enjoyed using the movie renting service once every two months. This option was only available to PVR subscribers. The participant admitted to sometimes reading the news on a mobile phone while watching TV "*because it is handy having it right on me.*"

The participant said when the decoder did not respond to the selections, the participant would just switch the decoder off at the plug. The participant struggled to read some of the labels, particularly the buttons that had two labels on them and doubled up the functionality. The participant had to bring the PRC close to their face and needed to focus in order to read the labels. The participant wanted a search option that would allow participants to type in the name

of a programme into a search bar, using predictive text, and the time and day of the show would be displayed. The participant did make mistakes when pressing the number buttons on the PRC which forced the participant to keep pressing the buttons until the correct combination was selected. It was noted by the participant that the colours on the TV screen were not easy to see, there was a blue button on a blue background.

Participant 4

Participant 4 was a PVR owner allowing the participant to access more features than available for non-PVR subscriber using PRCs. Participant 4 would typically watch TV in-between cooking and taking care of a one year old child. When the participant had time to watch TV they would look to see what channel was currently on, displaying a particular programme, and if nothing caught their attention they would go to a specific channel, or look at the catch-up list of series to see what the participant had missed. If Participant 4's child was around the participant would go to the children's channels or go to the playlist and replay a recorded programme the child enjoyed. Participant 4 did not always remember when a programme was on or what time it was on, so the participant used catch-up often to watch programmes they had missed.

The participant mentioned that it would be quicker to type in the name of a programme into a search bar, especially when the participant knew what they wanted to watch or record. The participant said, "P*erhaps the search option could give suggestions as you begin typing in the name like when you are typing a message on your mobile phone, like predictive text.*" Participant 4 enjoyed watching the trailers on the movie renting service "*it is a nice to have option … I prefer watching trailers for movies than reading about them.*"

Participant 4 never used the mute button but rather the pause button to silence programmes quickly so that the participant did not miss out on the programme. Participant 4 admitted to not being too adventurous with the PRC and did not know how all the buttons worked; the participant only used the buttons they needed. Participant 4 admitted that "*if something isn't instantaneous then I think that it isn't working properly.*" Participant 4 did not find any of the labels to be a problem and also said that they would use the audio feature (music), however, had never tried to use it.

Participant 5

Participant 5 typically watched specific preferred channels when they got home from work and knew what days certain programs were on. They claimed to be a "*creature of habit*" and

generally knew when their preferred programmes were on. The participant also said they had never used the TV guide magazine as the participant found it too difficult to read. Participant 5 claimed to not change the settings as the participant "*does not like to fiddle around.*" When the participant's child changed the settings for the TV, the participant was confused by the colours displayed on the TV and felt "*thrown off*". The participant said they would probably ask the child to change the settings back to normal.

The participant was frustrated with some of the sports channels that were available but did not play when selecting them. The participant thought it would be a good idea to hide the channels the participant was a not subscriber to. The labels on the PRC were fading and Participant 5 mentioned that they would need to buy a new one soon. The participant claimed to have used the audio button once before but was not sure how to get to the feature again. The participant admitted to asking the children for help with functionality the participant did not know how to operate and claimed not to be a "*techno revolutionary*" but would occasionally find new things.

Participant 5 said, "*The family often fight over the remote … they often lose it and have to search the house for it especially with the kids.*" The researcher noticed that when the participant pressed the TV button there was no response and the participant continued to press the button, regardless of the lack of response. Eventually the participant restarted the decoder. Participant 5 said they did not really have any problems with the PRC, but admitted to not getting the optimal use out of it.

Participant 6

Participant 6 admitted to not watching much TV. When the participant searched for something to watch they pressed the arrow button and displayed the channel grid of all the programs and scrolled up and down the grid looking for something to watch amongst the participant's favourite channels. The participant said, "*I know what my favourite channels are called but I don't know what their numbers are.*"

Participant 6 was noted to only make use of the audio button when the children had changed it to this feature and the participant's husband was unable to get back to the TV channels. The participant was unable to read some of the labels on the PRC since they had been rubbed off from general usage.

Participant 7

Participant 7 typically watched TV in the evening and scrolled through the information bar using the arrow keys. The participant searched for a specific programme to watch or searched for something that looked interesting. Participant 7 said, "*When I first bought the decoder I typed in the channel numbers using the number keys, but this was too time consuming and now I prefer to scroll through all the channels.*" Participant 7 never changed any of the TV settings and used the bare minimum of the PRC features.

Participant 8

Participant 8 said, "*I hardly ever watch TV*" and confessed to being a "*complete novice at using the remote.*" The participant said they would watch more TV if they had a PVR decoder to record the programmes. The participant said, "*I would like to record programmes that are on during the day, while I am at work.*" Participant 8 wanted to search for more information about programmes on another device since the participant claimed to be technically minded but did not like the layouts of the information displayed on the TV.

Participant 9

Participant 9 typically placed the TV on a specific channel during the evening and would channel hop if the programme was boring. The participant said, "*I just like to see what is on.*" Participant 9 would only use the audio feature once a month when playing bridge with friends and did not use it any other time. The participant thought the sizes of the labels were fine but the participant said, "*I do not like the labels and buttons on the remote that do nothing,*" for example, the record button and the text labels that the participant never used. The participant often miss-typed the number buttons because the participant generally looked at the TV and not the numbers on the PRC.

Participant 10

When Participant 10 wanted to watch TV they would typically begin with the news on a particular channel and would switch to another channel, and channel hop depending on what was on TV.

The participant said, "*I just restart the decoder when the display on the TV does something I am unsure of.*" The participant had no knowledge of what many of the buttons did. The participant found the PRC to be a nice size, "*it fits nicely into my hand*", but the participant would change

the arrow buttons to make them more obvious since they were black buttons on a black background.

Table 5.3 shows the buttons that were used by participants to operate certain functionality while demonstrating the tasks they accomplished during the CTA. The features were ranked according to the number of participants who operated them. The information and volume buttons were used the most whereas the PVR functionality and the settings menu were used the least. The buttons give an indication of which functionality is used by the user sample and potentially what buttons should be included in the VRC design. The various buttons/functionality were further grouped into higher level groups, for example, Channel Changing.

Table 5.3: Summary of Buttons and Functionality Operated by Users

Rank	Button/Functionality	HLG*	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	Information	Information	x	x	x	x	x	x	x	x	x	x
1	Volume (up/down or mute)	Sound	x	x	x	x	x	x	x	x	x	x
1	Arrow buttons (left/right/up/down)	Navigation	x	x	x	x	x	x	x	x	x	x
2	Numbers	Channel Changing		x	x	x	x	x	x	x	x	x
3	Programme up/down	Channel Changing	x			x	x	x			x	x
4	Language	Settings	x		x		x		x		x	
5	TV guide (virtual)	Information	x	x		x	x					
6	Banner	Reminders	x	x		x						
6	Auto-tune	Reminders		x	x		x					
6	Alt	Navigation	x	x	x							
6	Audio	Channel Changing					x	x			x	
7	Help	Information		x				x				
7	Movie renting services	PVR			x	x						
7	Channel grid	Channel Changing						x		x		
7	Playlist	PVR			x	x						
7	Shift	Navigation			x						x	
7	Record	PVR			x	x						
7	Play/pause/fast forward/rewind/stop	PVR			x	x						
7	Catch-up	PVR			x	x						
8	Main menu/Settings	Settings		x				x				

*HLG – Higher Level Group

The summary (Table 5.4) shows the context of use of the participants within this research and gives an indication that PRCs need to be used in a multitude of environments, with various lighting, and distractions. Therefore, the usability of the VRC needs to be designed for varying contexts of use. The different contextual environments are important to note so that VRCs can

cater for different changes in environments in which participants may use these devices. The main context of use was a well-lit room with background noise, with the participant sitting approximately two meters from the TV.

Table 5.4: Summary of Context of Use Environment

Setting	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Well-lit room	x	x			x	x			x	x
Semi-lit room			x	x						
Dim-lit room							x	x		
Kids running around			x	x	x	x				
Pets					x	x	x	x	x	x
Background Noise		x	x	x	x	x	x	x		
Drinking	x						x	x	x	
Eating							x			
Distance from TV in meters	2m	3m	2m	2m	5m	6m	3m	2m	4m	4m

5.4.2 Task Analysis

The following section outlines the goals for the task analysis. The following observations of participants interacting with the PRC, were confirmed with video during the contextual inquiry process. The list of goals comprised the tasks participants typically performed using particular buttons (functionality) on the PRC. A hierarchical task analysis (HTA) was used to categorise the tasks into a hierarchy of sub-tasks (Saffer, 2008).

5.4.2.1 Changing Channels

Viewing a programme on a particular channel was an inherent activity that took place when a channel was changed. The channel changing task was performed in various ways (scenarios) and the following were recorded from the participants' demonstrations.

Method 1

0 Change the channel

- 1 Press information button
  - 1.1 Information bar is displayed
- 2 Press arrow buttons left or right to scroll through information
- 3 Press Ok button to select channel to watch
- 4 Press exit to close information bar

Method 2

0 Change the channel

- 1 Press the channel numbers/digits on the PRC, for example 102

Method 3

0 Change the channel

1 Press programme up or down (next channel or previous channel)

Method 4

0 Change the channel

1 Press any arrow button (up/down/left/right)

1.1 Wait for channel grid to be displayed

2 Press arrow buttons (up/down/left/right) to scroll through channels

2.1 Find a programme on a channel to watch

3 Press Ok to select the channel

Participants employed various methods to change the channels depending on their contextual situations. Four out of ten participants pressed the information button to scroll across (left/right) to a specific channel. They did this when they were browsing through all the channels and were looking for something to watch (Table 5.5).

Table 5.5: Changing Channel Methods used by Participants

Method	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	x	x	x				x			
2		x	x	x	x	x	x	x	x	x
3	x	x		x	x	x			x	x
4						x		x		

The most common method used by the participants was Method 2, which consisted of pressing the specific channel numbers (digits) to find channels (Table 5.5). The least common method used by participants was method 4 which consisted of pressing the arrow keys to display the channel grid. These participants were unfamiliar with the PRC functionality and preferred to display all the channel options before selecting one to change to.

5.4.2.2 Alternate between Channels

Method

0 Switch or alternate between two channels

1 Press the Alt button when on a particular channel

1.1 Check the channel has changed to the previous channel being viewed

Three out of ten participants said they used the Alt button, mainly to avoid advertisements and because it was quicker to change between two channels rather than retyping in the numbers of the channels, or searching for a channel using the information button and arrow keys. The seven participants that did not use the Alt button said they never knew it existed. One participant said,

"*I do not use it out of ignorance.*" Two participants suggested it would be good to be allowed to alternate between more than two channels, especially when there were three programmes they were trying to watch at the same time, for example, during the Olympics.

5.4.2.3 Find a Programme to Watch

TV planning was an activity/task in which participants attempted to plan their programme watching ahead of time. Participants browsed through many different channels to try and find something of interest to watch.

Method 1

0 Find a programme to watch (plan to watch a programme)
- 1 Press TV guide button
- 2 Press arrow buttons up/down to scroll to the all channels option
  - 2.1 Press Ok button to enter all channels option
- 3 Press arrow buttons to scroll left/right/up/down until a preferred programme is found
  - 3.1 Take note of the date and time a programme begins on a particular channel
  - 3.2 Press Ok button once to select banner option
  - 3.3 Press Ok button twice to select auto-tune option
  - 3.4 Press record button to record the programme on a particular channel
- 4 Press exit to exit TV guide menu

Method 2

0 Find a programme to watch (plan to watch a programme)
- 1 Press information button
  - 1.1 Information bar is displayed
- 2 Press arrow buttons to scroll left or right through all the channels
  - 2.1 Take note of the date and time a programme begins on a particular channel
  - 2.2 Press Ok button once to select banner option
  - 2.3 Press Ok button twice to select auto-tune option
  - 2.4 Press record button to record the programme on a particular channel

The researcher noticed that four participants operated the TV guide button when they knew particular programmes were going to be broadcasted (Table 5.6).

Table 5.6: Find a Programme to Watch Method used by Participants

Method	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	x	x		x	x					
2			x			x	x	x	x	x

Six of the participants that did not use the TV guide found programmes to watch in the 'spur-of-the-moment' while already watching TV. Generally the participants were relaxing and wanted to find something to keep them entertained and pass the time. One participant said, "*I just like to see what is on.*" One of the participants liked to ask his friends about what programmes were on and the time they were going to start, for example, the date and time of the rugby. Two of the ten participants still use the TV guide magazine, reason being that they like to flick through the pages, and the TV guide onscreen is a bit confusing and overwhelming.

5.4.2.4 Set Reminders

The banner cues the viewer that another programme will be starting soon and auto-tune automatically changes the current programme being viewed, on a specific channel, to another programme on the channel that was set to be auto-tuned.

Method

0 Set a reminder
- 1 Press information button
  - 1.1 Scroll to a particular channel
  - 1.2 Select/highlight the programme to be reminded about
- 2 Press the Ok button
  - 2.1 Press Ok button once for banner
  - 2.2. Press Ok button twice for auto-tune
- 3 Press exit

Four out of the ten participants used auto-tune when they knew they really wanted to watch the programme, regardless of what they were currently watching. While four out of ten participants preferred the banner and liked to be reminded about the programme. The banner feature gave participants the option to decide at that moment whether they wanted to change to the programme or continue viewing their current programme. Interestingly, one participant chose to write down reminders on a piece of paper for each of the programmes the participant wanted to

watch. The participant said, "*I wasn't told about that functionality*" referring to the reminders. In addition, another participant said, "*It would be nice to have a reminder on your phone, because it is closer to you and then if I am cooking in the kitchen, at least I will hear my phone and know that my programme is about to begin.*"

5.4.2.5 Setup Favourite Channels

Method

0 Setup a list of the participant's favourite channels
- 1 Press one arrow button (up/down/left/right)
  - 1.1 Check channel grid display on TV
- 2 Press arrow buttons (up/down/left/right) to scroll through the channels
- 3 Press white colour button to add channel to favourites list
- 4 Press exit to get out of the channel grid

The reason favourites exist is to reduce the options of channels participants have to scroll through. Nine of the ten participants did not know how to set their favourite channels, however, they all had favourite channels whose content they enjoyed watching. Participants wasted a great deal of time scrolling through channels whose content was of no interest to them. One participant had tried to set favourites but did not know how to access them initially. Once the participant figured out how to setup favourite channels they found it very useful and a time saver since they did not have to scroll through all the channels.

5.4.2.6 Play Recorded Programme from Playlist (PVR only)

The playlist (colour buttons) and play/fast forward/rewind/pause/stop buttons only functioned on PVR subscribers' PRCs however, if these buttons appeared on standard decoder PRCs they were deactivated and served no purpose.

Method 1

0 Play/fast forward/rewind/pause/stop a programme on the playlist
- 1 Press playlist button (red colour button)
  - 1.1 Check playlist is displayed
- 2 Press up or down arrow buttons to scroll through playlist of recorded programmes
- 3 Press Ok button to play the programme
  - 3.1 Check if programme is playing
    - 3.1.1 Press fast forward button to fast forward through programme
    - 3.1.2 Press rewind button to rewind through programme
    - 3.1.3 Press pause button to pause the programme
- 4 Press stop button to stop the programme
- 5 Press exit twice to get back to normal TV viewing

Method 2

0 Play/fast forward/rewind/pause/stop a programme on catch-up the playlist

1 Press playlist button (red colour button)

1.1 Check playlist is displayed

2 Press arrow buttons to scroll left or right to catch-up playlist

2.1 Wait for catch-up playlist to be displayed

3 Press up or down arrow buttons to scroll through catch-up playlist

4 Press Ok button to play the programme

4.1 Check if programme is playing

4.1.1 Press fast forward button to fast forward through programme

4.1.2 Press rewind button to rewind through programme

4.1.3 Press pause button to pause the programme

5 Press stop button to stop the programme

6 Press exit twice to get back to normal TV viewing

Six of the ten participants were unaware of what the colour buttons did (non-PVR subscribers) as they were placed on the PRC but served no purpose. One participant commented that they (the extra buttons) just took up space on the PRC. Two of the ten participants only operated the playlist button since they were PVR subscribers and could access their recorded programmes via the playlist, but they did not know what the other colour buttons (bookmark, slow motion, status bar, and PVR menu) were used for. One participant in particular said, "*I prefer to record something and then watch it later when I have time*." The participant enjoyed using the catch-up list when there was nothing else to watch on TV and the participant was unaware what purpose the other colour buttons served. Another participant had issues when rewinding/fast forwarding through programmes and said, "*I don't like it (the buttons), sometimes it is fast and other times it is slow*". Although two participants in the study were PVR subscribers, four participants in total were familiar with PVR functionality.

5.4.2.7 Record a Programme

Method

0 Record a programme

1 Press record button when on a programme on a particular channel

There were only two participants that were PVR subscribers. The participants really enjoyed recording programmes and said "*it would be nice to be able to record when you are outside the house…that would be brilliant in case you are at someone's house and they don't watch your*

programme". Another participant had a record button on their PRC however the button did not do anything and served no purpose.

5.4.2.8 Obtain Help

Method

0 Obtain help in order to solve a problem
- 1 Press help button
  - 1.1 Press arrow buttons to scroll through help options
  - 1.2 Press Ok to select the help needed
- 2 Press exit when complete

Only two of the ten participants had operated the help button before. One participant had used it once when trying to unblock a channel but had never used it again and another participant tried to use the help button during the CTA, however, the button was not working. Eight of the ten participants were unaware that there was a help button and said they mostly did things through trial and error. One participant said, "*I never noticed the button and I wasn't aware that there was a help button.*"

5.4.2.9 Find Information about a Particular Programme

Method

0 Find information about a programme
- 1 Press information button twice
  - 1.1 Read information about programme
- 2 Press exit button twice when complete

All participants pressed the information button to find out more information about the programmes they were watching, or going to watch. One participant mentioned going onto review websites, such as Rotten Tomatoes (http://www.rottentomatoes.com/), in order to see more information about a particular series or movie. All participants chose programmes based on the information given when pressing the information button (Rotten Tomatoes, 2015). The information included a synopsis of the programme. If the programme was a series the season and episode numbers were shown, and if the programme was a movie the actors and directors of the movie were shown. All participants mentioned this information to be valuable. One participant said that "*it would be nice to have a preview for the movies*" instead of reading the information about a movie.

5.4.2.10 Change the Volume

Method

0 Increase or decrease the volume

1 Press volume up button to increase the volume

1.1 Press volume down button to decrease the volume

1.2 Press mute button to silence programme completely

One participant in particular always used the volume and mute buttons to control the decoder volume since their TV did not have a remote control. The same participant's mute button did not mute the sound completely at first, but it just lowered the volume (quietens it), then if the mute button was pressed again it muted the sound completely. The participant really liked this option especially when talking to a friend and watching TV. All the participants were observed to have used the volume buttons even though they did not explicitly mention using them.

5.4.2.11 Specify the Language

Method

0 Specify the language wanted

1 Press language button

2 Press arrow button up or down to scroll through options

3 Press Ok button to select preferred language option

4 Press exit

Six participants had operated the language feature to change the language from family to original. Two participants said, "*I do this when watching a movie that keeps blocking out the swearing and affects the flow of the movie.*" One participant was unable to change the existing language selection to English saying that there was a fault with the language functionality. It was set to Spanish and when the user tried to change the language the TV malfunctioned.

5.4.2.12 Exit a Feature

Method

0 Exit a feature (information display on TV)

1 Press the exit button once or numerous times

1.1 Check that TV display is clear of the feature being displayed

All participants were familiar with the exit button in order to exit a feature and return to normal TV viewing, and this button was used often.

Finally, by observing the participants using the PRC to interact with the TV, it is possible to deduce a list of features and functionality they found to be useful and problematic as shown in Table 5.7.

Table 5.7: UX of PRC Functionality

Physical Remote Control	
Supporting UX	**Affecting UX**
A customised grouping of channels can be created (favourites)	Channel grid useful to see, but blocks vision of programme on TV
Watching previews in movie renting service	The awkward UI for creating a scheduled recording for a programme
Mute button	Instructions are too subtle on screen, for example blue colour button on a light blue background
Information button	Settings options not always intuitive
Numbers for specific input of channels	Customisation of favourite channels was not easy
Alt button to return to previous channel	Some text shown on TV screen is too small to read
Virtual TV guide to look for future programmes	Slow response of the decoder to button presses on the PRC
Shortcut buttons (red button for playlist)	Terrible search facility (not available for all participants)
A way to navigate up and down to the next programme on another channel	Awkward tedious text-input using multi-tapping
Size of the PRC fits nicely in the hand	Small labels
Banner giving users the choice if they want to watch the programme or not	Dual functionality of buttons, confusing at times (shifting between TV and audio)
Auto-tune, if you know you want to watch a programme	Arrow buttons not obvious enough (black on black)
	No use for colour buttons on non-PVR subscribers' PRCs
	Help button did not work
	Labels rub off, have no idea what functions they perform
	Some buttons are too small, for example the numbers and programme up and down buttons
	Always need line of sight to TV with PRC
	Cannot alternate between more than two channels

5.5 Discussion

It was important to understand that all participants operated PRCs in diverse environments. Participants were seated on couches in comfortable, familiar, natural settings, with their PRC in their hands. The usage of the PRC, as well as the interaction of the user with the PRC and TV, better informed what VRCs should cater for. Arhippainen and Tahti (2003), Love (2005), and Lorenz *et al*. (2009) expressed that it was important to design for devices that were usable in varying contexts of use. Therefore, the remote controls should be able to be used in comfortable and relaxed environments, exhibiting simple interface layouts that could be used with ease and little thought, so to encourage a positive MUX. The differences between the environments were the lighting in the rooms (dim to well-lit), and the various distances at which participants were seated from the TV, which made it difficult for some participants to read text on the TV screen. Smartphones have illuminated screens that allow text to be read in the dark with ease. Cesar *et al*. (2008) discussed feedback that was displayed on a second screen rather than on the TV, allowing the distance between the TV and the participant to be reduced which enables better

visibility of information (Lorenz *et al*., 2009). It is important to have text that is legible (large font size) and this finding is reiterated in section 3.7.3 and section 4.2.5. Tiresias (2009) suggests that large sized fonts should be used to make labels legible. Participants were observed to multitask while watching TV, for example, cooking while minding children; and had many distractions, such as barking dogs or visiting guests. These contextual influences need to be considered when designing VRCs in order to enhance the user experiences. Arhippainen and Tahti (2003), Love (2005), and Schmidt (2005) recognised that the context and environment need to be considered when designing for more usable devices, which may result in more successful user experiences.

Some participants were familiar with the layout of the PRC and did not look down at the buttons, relying only on the tangible nature of the buttons, while other participants were unfamiliar with the layout of PRCs and looked down at them. Virtual buttons lack the natural tactile feedback qualities of PRC physical buttons, which requires users to be more careful in their selections, requiring them to learn new interaction methods and forcing users to look down at the UI (Pan & Ryu, 2009; Pirker *et al*., 2010). This result is echoed in section 3.5 by Hoggan *et al*. (2008) and Pirker *et al*. (2010). It is important to incorporate tactile feedback for virtual buttons, giving users the response they need to confirm their selections, similar to how users receive tactile feedback from the PRC. Sufficient feedback is important for users to know that the system is responding to their requests (Nichols & Myers, 2003). Visual and/or tactile feedback should be given to users immediately (100ms) when interacting with the device (Roto & Oulasvirta, 2005). If the length of time for feedback is longer than four seconds, additional feedback such as a spinning logo or extra visual feedback should be given to users in response to the button presses.

Different types of reminders were believed to be useful when finding programmes to watch. Users should be able to set visual (reminder message) and audio reminders which would be valuable, since users may not be in the same room as their TV when their programme is screening, and may have forgotten about a reminder they had set. The need for feedback to be given more than once and in different ways is supported in section 3.5. Yasumura *et al*. (2006) and Turunen *et al*. (2009) suggested that feedback should be customisable for users, for example, if they are visually impaired, or for various environments.

Users changed the channels in a variety of ways, ultimately wanting to select a channel in the quickest manner appropriate to their situation. According to the HTA, the quickest ways to change the channel was to press the channel number buttons or the programme up and down buttons. The results showed that users enjoyed browsing through all the channels or looking for

specific channels. Future designs need to cater for multiple navigation pathways depending on the skill of the user, for example, if they know the channel number or not. The screen layout and navigation are important components that should help users to easily search through channels and select the appropriate channel they wish to view. This result is supported in section 3.6 and section 3.7.4. Stockbridge and Mughal (2007), and Heo *et al*. (2009) all advocated clear, structured presentation of information that was more understandable and easy for users to access. Easy navigation through the screens is required to help improve the usability of the UI and ultimately the user experience as reiterated in section 4.2.6. (Norman, 1988; Ji *et al*., 2006; Maassen, 2008). All features should let users easily exit them and constant visual indicators should be given to users allowing them to explore the system, so they do not feel trapped (Stockbridge & Mughal, 2007).

When information was displayed on the TV screen, users commented that the TV screen looked overwhelming and complicated. Users did not like when their screens were blocked by the channel grid and preferred not to change from the programme they were watching when searching for more information. A second screen is useful to display information without blocking the users' view of the TV (Cooper, 2008). The use of the second screen would enable users to browse through channels without interrupting other users' viewing, as suggested in section 4.3.6. An uncomplicated layout of the information arranged in a manner that is easy-to-read may help to improve the usability (Berglund *et al*., 2006; Stockbridge & Mughal, 2007; Lee *et al*., 2008; Simon *et al*., 2013).

All participants knew what their favourite channels were but had never setup a list of their favourites. Users scrolled through many channels that were of no interest to them to get to their favourites. Users needed an easy manner of customising a list of channels to a smaller selection of the most viewed channels. Frequently accessed items should be placed in a more prominent position to speed up navigation and improve the operation sequence of users, and the features they access. This is reiterated in section 4.2.2 (Klockar *et al*., 2003; Venkatesh *et al*., 2003; Cooper, 2008). The method of adding favourite channels should be simple and allow users to quickly and easily access their favourite channels.

There was no suitable search facility available to users to easily navigate through masses of information (various channels and programmes). An appropriate search feature is needed that allows users to type in text, using a keypad layout that is not cumbersome and is familiar to most smartphone users (a QWERTY keypad was suggested by users). This is echoed in section 4.2.8. Users accessed the virtual TV guide to find programmes to watch but had to press many buttons

to get to the programmes they wanted to watch. There is a need for simple and easy-to-access navigation and menus that contain enough information to inform the users about the programmes available (section 3.6.1. and section 4.2.6). Berglund *et al*. (2006) and Lee *et al*. (2008) both suggest that simple and easy-to-use screen layouts help users to find information quickly. All participants agreed to reading information about programmes they chose to watch. This was a very important aspect of TV watching. The information must be easily accessible and informative (Morville, 2004; Maassen, 2008) and it must be laid out in a readable format so that users can make an informed decision about whether they want to watch the programme or not. Users should be allowed to access and search for external sources (websites) to acquire information regarding movie reviews and previews. This gives users control over the amount of information they want to access. Tognazzini (2007) said that systems should attempt to anticipate users' needs and wants, and make available to the users all the information and tools needed to complete their tasks. Users often pressed shortcut buttons (TV guide and Alt) which were very useful for tasks that were frequently demonstrated, however, they struggled to demonstrate infrequent tasks, for example, changing settings. Shortcut buttons, such as the Alt button on the PRC, are convenient for users once they learn what each button does, since they provide quick access to main features (Radioland, 2006; Cooper, 2008).

Carmichael *et al*. (2006) and Tiresieas (2009) reported that PRC labels should be a legible size and durable to resist being rubbed off with excessive use. The CTA supported this literature and observed that the labels on the PRCs rubbed-off and at times were too small. It is important that buttons do not rub-off and can be enlarged to a legible size (section 3.7.3 and section 4.2.5).

Some of the buttons on PRCs (arrow buttons) were too small or had no purpose (colour buttons on non-video recorder PRCs). Karlson and Bederson (2008) and Park and Han (2010) agree that the button size needed to be increased to between 7mm and 10mm, and buttons that served no purpose should be disabled or eliminated. This finding is supported in section 3.7.2, section 3.7.4, and section 4.2.3. The colours displayed on the TV screen were not always easy to see (blue button on blue screen). The colours used should give enough contrast for users to differentiate and identify the various features (Stockbridge & Mughal, 2007; Tognazzini, 2007). This was also suggested in section 3.7.3 and section 4.2.5.

Only two users had operated the help feature before, commenting that they had never noticed the help button and did things through trial and error. A context sensitive help feature should be available on each screen which gives users easy access to valuable help for the specific screen, however, users should have the option to hide this feature. A more visible help feature can

improve the system usage and help novice users to become more familiar with the features available to them as recommended by Nielsen (1993), Stockbridge and Mughal (2007), and Shneiderman and Plaisant (2009). Participants were noted to do things by trial and error during the CTA and the relevance of a help menu was questionable.

It was observed that the sound functionality was often regulated by users (Table 5.3). For this reason it may be helpful to make the volume easily accessible and in a prominent position on the UI. All the settings functionality needs to be simple and uncomplicated. The conceptual model of the system needs to be aligned with users' mental models of selecting an item they want, thereby giving users the ability to select an option and change the setting (Klockar *et al*., 2003). The settings that are not changed often should be placed on a different screen to all the frequently used buttons, as they may help to improve the usability and reduce the complexity of having too many buttons, as suggested in section 4.3.2 and section 4.3.4 (Nichols & Myers, 2003). Users specified the language they wanted to use by selecting family or original (included profanity) and the process was a simple one, and should be continued.

To enhance the user experiences, Morville (2004) stated that it was vital that features were accessible and findable to all users. All buttons (functionality) were permanently available to all users even though in some cases the functionality (record, play, to name a few) did not work on the particular PRC (non-PVR PRCs). Buttons that serve no purpose to the user should not be included on the device (too many buttons) since they take up space and make the interface more complex (Roduner *et al*., 2007). This finding was reiterated in section 3.7.4 and section 4.2.6. Cooper (2008) confirmed that many users stick to the basic buttons they know as shown in the CTA, Many users have little knowledge of the purpose of several of the buttons and simply ignore them. The placement of well-defined labels close to the buttons may help to improve the understanding of some of the buttons.

5.6 Conclusion

This chapter established the environmental contexts that PRCs were used in, common tasks the users frequently completed whilst using the PRC to interact with the TV, as well as some tasks and functionality that were troublesome or observed to be useful by the participants. VRC designs should consider the relaxed and comfortable environments that users generally interact with TVs, the different lighting settings, as well as noise and external distractions of everyday life. This reiterated the review of literature regarding the various contexts in which users develop a user experience. The CTA gave insight into the following tasks that were observed to be the

more frequent activities users completed. Users should be able to change the channels, find a programme to watch, set reminders, find information about a particular programme, change the volume, specify the language (change the settings), and exit a feature. VRCs at the very least should cater for all of these activities, so that users will feel that they can accomplish their everyday tasks with ease, in the hope of improving the user experience. The following tasks were used less-frequently by users, however, they were seen to be important to the TV watching activities and at times they were troublesome, or observed to be useful by the participants. The tasks were alternating between channels, setting up favourite channels, playing recorded programmes on the playlist, recording a programme, and obtaining help.

The following usability issues were uncovered during the CTA and need correcting when developing VRCs. The instructions or feedback (text on TV screen) was not visually clear or too small since the incorrect colours were used (blue button on blue background), or the font size was too small. The settings options were not always intuitive and the customisation of favourite channels was cumbersome. The search facility was not user friendly and the multi-tapping text input method was awkward for users. Small button labels made it difficult for users to read what the buttons were for, and the dual functionality of the buttons was confusing for some users. The colour of the buttons and the functionality they represented was not always clear (a back arrow on black button) since the incorrect combination of colours were used. Some buttons on the PRC were of no use for non-PVR users and the help button did not work on some PRCs. The labels on the PRC rubbed off, or faded away, for many of the users and participants forgot what functions those buttons performed. Participants noted some of the buttons to be too small, for example, the numbers (channel) and programme up and down buttons. These findings were supported by the review of literature regarding the mobile user interface design guidelines that should be followed (Chapter 3), and the current usability issues of PRCs and VRCs that need to be overcome (Chapter 4). The CTA also revealed that the following functional interface guidelines may support the usability of a VRC, and contribute to an improved UX (Table 5.8).

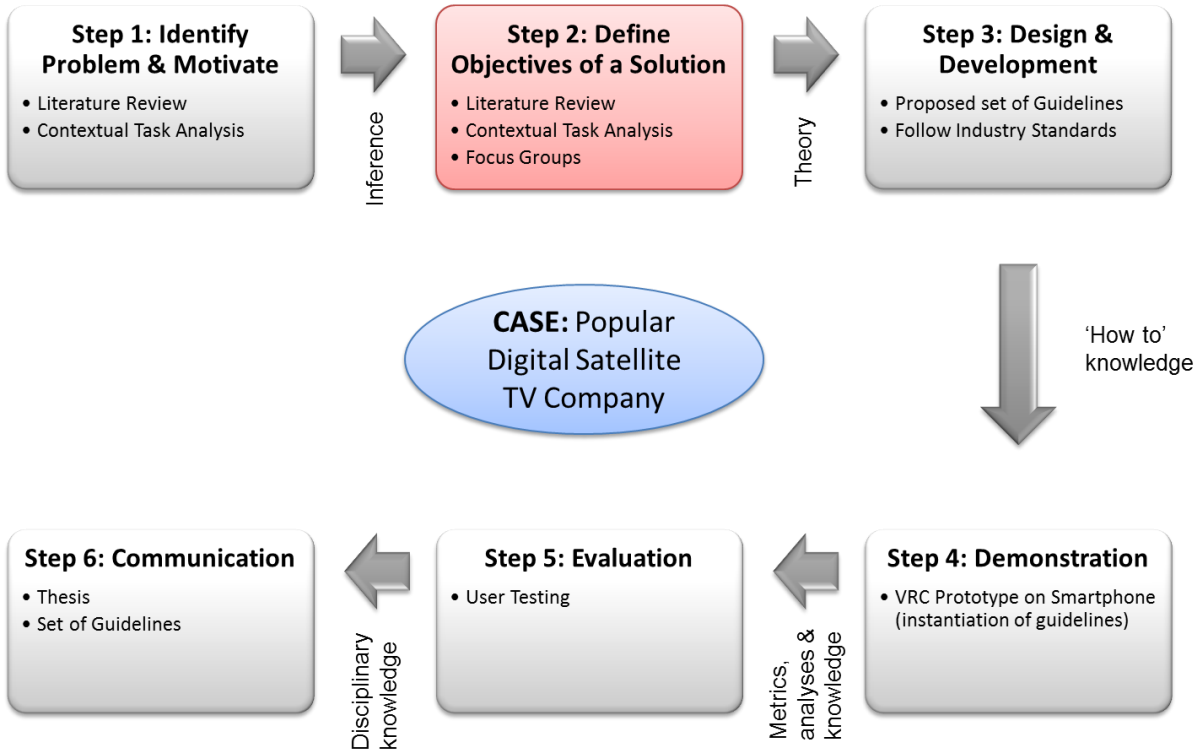
Table 5.8: Functional Interface Guidelines to improve UX

Functional Interface Guidelines	Source
Feedback: Give users appropriate feedback on the expected interface • Display all feedback on second screen (not the TV) • Include visual or aural banner and auto-tune reminders	
Functionality: Provide users with the means to carry out tasks that simplify their interaction with the remote control • Allow users to add a list of favourite channels • Give users the ability to search for programmes • Provide users with a manner of alternating between multiple channels • Give users context sensitive help • Settings should be simple and uncomplicated	
Information: Give users ways to access the information they require • Provide users with a TV guide that gives them enough information about the TV programmes • Give users the ability to acquire additional information from external sources (internet) • Provide users with a simple way to access more information, for example an information button	Section 5.5
Buttons: Provide buttons that have one purpose and make operating the remote control easy • Use shortcut buttons for frequently used functions • Make the volume control easily accessible • Allow for numeric input to change channels quickly • Most buttons should only have one purpose	

Chapter 6 Brainstorming Focus Groups

6.1 Introduction

Chapter 6 contributes to step 2 of the DSRP model which relates to defining objectives of a solution for the research. This is completed through brainstorming focus groups.



The purpose of this chapter is to explore new ideas for VRC functionality that may enhance the UX for users and improve upon current PRC functionality, to understand what the most commonly used touchscreen interaction techniques are, and to gather ideas on how to represent certain UI elements on VRCs. This chapter discusses the brainstorming focus group method that was used to obtain data regarding the exploratory features and ideas for VRCs. Brainstorming focus groups are a mixture between creative thinking that generates ideas (brainstorming), and interactive discussion groups that gather individuals' ideas about certain topics (Kuniavsky, 2003; Lazar *et al*., 2010). These focus groups help to reveal users' thoughts and feelings about the specific topics to improve existing PRC functionality. This chapter aims to answer the third research sub-question, "*What user interface design features should digital TV virtual remote controls contain?*"

6.2 Rationale for Technique

Bruseberg and McDonagh-Philp (2001) used focus groups, as a base method, to directly inform the new product development process for a range of mainstream domestic consumer products in order to gather user needs, aspirations, and emotions regarding the products. Bruseberg and McDonagh-Philp used brainstorming methods in their focus groups to generate ideas for users' ultimate wish lists for the new products and this was performed in a non-judgemental manner (all ideas were valid). The results indicated that focus groups actively offer flexible and informal techniques that assist with communication between researchers and users, and allows for the collaboration of ideas and mutual understanding. Similarly, Black *et al*. (2001) used focus groups as part of the exploratory stage of their research and took advantage of the flexible nature of focus groups to explore consumer reactions to new product concepts for internet financial services. Maguire and Bevan (2002) used focus groups, as part of the user needs identification for future financial services to be displayed through home devices such as the TV or PC. The focus groups allowed Maguire and Bevan to identify innovative ways to deliver the future services to users by rapidly gathering a wide variety of user views in a short amount of time. Similarly, this research will use brainstorming focus group sessions to gather ideas for users' needs regarding VRCs.

Koskela and Väänänen-Vainio-Mattila (2004) evaluated the usability and living experience of using three different UIs: a PC; media terminal; and mobile phone. The evaluation of the three UIs was completed, for smart home environments, using focus groups, laboratory tests, and interviews. The focus groups were used to collect information about user attitudes and possible predispositions to the new types of interaction in a future smart home. The results showed that the mobile phone was the primary and most frequently used UI during the trial period in the smart home environment and was well suited for instant control. This chapter is therefore guided by the methods used in Koskela and Väänänen-Vainio-Mattila's research by using focus groups to elicit information about users' attitudes and ideas about new types of interaction. In the same way, Berglund *et al*. (2006) used focus groups to study audiences' attitudes and anticipated interest toward the new paper remote product. The results highlighted the qualities that users regarded as important such as disturbance, mobility, and availability, for the development of the new paper remote. The results indicated that the methods used in Berglund *et al*. (2006) help to elicit important information regarding future product developments and the attitudes users have towards the new products. In contrast to the above studies, Schirr (2012) studied the flaws of group methods to generate customer ideas and showed evidence of the ineffectiveness of group research through summarised literature that was published outside of new product development

and the business realm. Schirr stated that although group methods (focus groups) may have a role in the early stages of innovation to promote distribution and implementation of user information; group methods should preferably be used after information has been gathered through individual research methods (similar to CTA method). This research used brainstorming focus groups as a method to elicit user ideas and information about new products (VRC), however, these methods were only used after rigorous individual processes (review of literature and CTA) were performed.

Van Kleef, van Trijp and Luning (2005) established a set of guidelines for the appropriateness of methods, for example, focus groups, in all new product development processes. Van Kleef *et al*. (2005) identified the 'voice of the consumer' to be a critical success factor in new product development and presented guidelines and details for the use of particular methods when developing new products. Van Kleef *et al*. (2005) showed that focus groups are particularly appropriate for incremental products, or for products that are updated versions of existing products. The interactive nature of focus groups allowed statements from one participant to trigger comments made by others (van Kleef *et al*., 2005). Similarly, this research used focus groups to elicit information from users in order to improve upon the designs of the PRC and create an enhanced VRC, with modifications guided by the brainstorming focus groups and the other methods (CTA) used within this research. Van Kleef *et al*. (2005) guided this research with regards to the methods and techniques needed to correctly execute focus group studies.

Focus groups were used in this research, using a semi-structured interview format, to reveal the target audiences' desires and experiences as stated by Kuniavsky (2003) and van Kleef *et al*. (2005). The focus groups were able to take on a flexible format that focused the group's discussion but allowed conversation to develop as new topics emerged, detailed by Bruseberg and McDonagh-Philp (2001), and Maguire and Bevan (2002). Focus groups are appropriate for research that is trying to explore and find out the needs and motivations of why an audience behaves how it does, first-hand experiences, and values of a group of people. Focus groups provide qualitative data from a sample of the target population. Their results cannot be quantified or generalised to the whole population as suggested by Bruseberg and McDonagh-Philp (2001), and Kuniavsky (2003).

This research used focus groups to explore possible future considerations/features for VRCs and different ways of interacting with them. The main objectives of the brainstorming focus groups in this research were:

- to explore new possible functionality participants wanted to have on VRCs in order to overcome the usability issues of PRCs as mentioned previously in the literature (Section 4.2), and to create suggestions for new possible features.
- to discover what the most commonly used touchscreen (gesture) interaction techniques were to help support the interaction of participants with VRCs. Identifying the common interaction techniques used by participants enables the researcher to fully utilise the touchscreen technology when creating and designing VRC UIs.
- to discuss what types of design elements participants would prefer to represent certain functionality on VRCs in order: to gain some ideas of how the functions could be displayed on screens; to understand the interaction techniques participants would instinctively employ to interact with those functions and complete the tasks; and to ultimately enhance the UX.

6.3 Method

6.3.1 Participants

The age groups used in the study were based on the popular digital satellite TV provider's statistics. The age groups for the approximately 3.6 million subscribers have been divided into six categories as shown in Table 6.1 (Wentzel, 2011). The 15-19 age group was not used for this research since part of the group of participants were minors. It was concluded that having at least two participants per age category (at least 1 participant in each category for the categories 50-60+) would represent the convenient sample needed for the research. The same convenience sampling technique that was used in Chapter 5 was also applied in this chapter (Tullis & Albert, 2008).

Table 6.1: Population Sample (Wentzel, 2011)

Age Category	Representative base	Participants
15-19	12%	Out of scope
20-29	23%	2
30-39	23%	2
40-49	18%	2
50-59	12%	1 or more
60+	12%	1 or more

The participants for the brainstorming focus groups were chosen as a stratified sample of the target population. The researcher interviewed all the participants prior to the focus group sessions in order to limit the chance of discussing topics with participants that misrepresented their experiences and did not 'qualify' for the participation criteria (Kuniavsky, 2003; Lazar *et*

al., 2010). The sample of participants used in Chapter 6 was different to the sample used in Chapter 5. It was pertinent that the participants had been subscribers to the popular digital TV broadcaster for at least six months, so that they had an understanding of the current functionality available and interactions with the system; as well as being able to comment on functionality that was not available at present. It was also important that the participants were familiar with touchscreen technology, to get valuable opinions about the discussion topics. The researcher assessed which participants had similar interests to make a homogenous group with good synergy, in order to help make the participants feel more comfortable during the discussions, and to reduce the anxieties participants may have felt, as suggested by Kuniavsky (2003).

Two brainstorming focus groups were used to represent a spectrum of the age groups of the target population, for the popular digital TV broadcaster (Table 6.1). The reason the focus groups were split into two groups was to allow for more homogenous groups of subscribers and was not for comparison purposes. The two brainstorming focus group sessions were held at the Information Systems Department at Rhodes University, in a seminar room on different days. The first session (Focus Group 1) comprised two males and three female participants in the 20-39 (20-29 and 30-39) age categories; and the second session (Focus Group 2) included two males and three female participants from the 40-60+ (40-49 and 50-60+) age category.

Another important reason for splitting the focus groups was to lessen the amount of people in each group since there was only one researcher capturing the data. Each focus group had five participants. Adams and Cox (2008) recommend that a focus group should not exceed six or seven participants since participants were likely to break off to talk in sub-groups and leave people out of discussions. However, if the focus group is too small (less than three people), it becomes harder to keep the conversation going. Nielsen (1993) and Kuniavsky (2003), both suggested that between six and ten people is a good size for a focus group, however, due to the possibility of breakout conversations occurring and only one researcher available to control the group, only five participants were chosen per group.

6.3.2 Procedures

The focus groups were conducted according to the methodology as described in Kuniavsky (2003). The two focus groups followed exactly the same procedures. The same questions related to future considerations, interaction techniques, and designs. They were asked in the same order (Table 6.2), giving enough time for each topic and allowing the discussion within each focus group to bring out the subtleties of the different participants. The semi-structured nature of the

interview process allowed the researcher to probe further into any topics that arose during the focus group session (Kuniavsky, 2003; Creswell, 2009; Lazar *et al*., 2010). Participants sat in a half moon seating plan so that all participants could be in full view of each other and that they could be videotaped.

Table 6.2: Topics and Questions used to guide the brainstorming focus groups

Topic	Questions
Future Considerations	1) What features would you like to have on the VRC?
Interaction Techniques	2) Has anyone ever used gestures before? 3) What are the most common types of gestures you have used? 4) What was the context you used those gestures in? For example at home, work etc.
Design	5) If you had a VRC what gestures/graphics/features would you prefer to represent the following tasks: • Change the channel • Alternate between channels • Find a programme to watch • Setup reminders • Setup favourite channels • Play recorded programmes from playlist • Record a programme • Get help • Find information about a particular programme • Change the volume • Specify the language • Exit a feature

All the common problems of group-think and group dominance were considered and participants' biases were limited as much as possible (Kuniavsky, 2003; Adams & Cox, 2008). A few of the common problems are:

- Group-think: when participants have a tendency to want to agree with other participants in the room. This bias was limited by asking participants individually what they wanted and it was reinforced throughout the focus group sessions that each participant's opinions were valid and that earnest disagreement was encouraged.
- Group dominance: when one individual tries to dominate the focus group discussion. This bias was limited by trying to draw attention away from the dominant participant when they were talking too much and to try and focus on the less outspoken participants.

This allowed the researcher to get an indication of who the outspoken/quiet individuals were and seated them in the half moon seating plan accordingly (Kuniavsky, 2003). Labels of all the participant's names were printed out and strategically placed on the tables when the participants entered the room in order to keep control over the group. The outspoken participants were placed close to the researcher and the quieter participants were placed across from the researcher to keep eye contact with them. This helped to control the participants and the flow of the discussion (Kuniavsky, 2003).

The brainstorming focus groups began with an introduction and warm-up which involved telling the participants about the research and the aims of the focus group. It was emphasized that their thoughts and opinions about the various topics were of particular importance to the process, and that they should be as candid as possible during the casual conversations. They were also told that their opinions would not hurt anyone's feelings and that no answer was right or wrong. Participants were asked to speak one at a time in order for all their responses to be heard and taken into consideration. Participants were asked if they had any questions before the focus group began, and once all uncertainties were addressed participants were asked to sign a form consenting to the research, and to them being video-recorded. Participants were asked to introduce themselves and to mention their favourite TV programme as an ice breaker before the general discussion continued.

The general discussion included asking participants to think about their digital TV PRCs at home and how they currently used them, and what they could do with them. Participants were allowed to express their views and experiences regarding their usage of PRCs. This process was used as a means to get the participants to talk and to guide the participants into thinking about remote control technology and its functionality, in order for them to think creatively for the remaining questions (brainstorming ideas). The participants were probed about the reasons as to why they wanted certain extra functionality (features) on VRCs and how they wanted the functionality to be represented on VRCs, whether in the form of gestures, graphics or text. The discussion was then focused on three topics (Table 6.2) relating to VRCs and touchscreen technology in order to accomplish the objectives specified previously. Participants were asked the following questions from which discussions developed:

1) The future considerations question was asked in order to understand what features participants wanted on VRCs and to overcome the current limitations that PRCs had, or features that PRCs may not have provided.

2) The interaction technique questions were asked to understand what the common gestures were that most participants used in order to employ up-to-date technologies to improve interactions with VRCs and to overcome some of the usability concerns in PRCs. Participants were also asked about the context in which they used certain interaction techniques in order to understand the contextual factors that may have influenced participants.
3) The design questions regarding the tasks were explored, as they were the tasks that users performed during the contextual task analysis (Section 5.4), and the questions were asked in order to acquire some ideas of how participants would like to display certain features on VRCs. The questions also revealed how users would prefer to interact with those features and perform the tasks. It was important to ask the participants how they would record or play recorded programmes using a VRC, since these extra features were available to PVR subscribers and needed some consideration.

Once the researcher had discussed and covered all the topics listed above, there was some open discussion time so that any other queries could be answered. The focus group session was then concluded and all participants were thanked for their time and contributions to the focus group.

The narrative information from all participants in the focus groups was collected and transcribed. The data was further analysed using the same thematic analysis method used in Section 5.3.2 (Braun & Clarke, 2006). It was used to help describe and organise the data set in detail, and understand different aspects of the research topic by combining the meaning of the analysis within their particular context (Kuniavsky, 2003; Loffe & Yardley, 2004). The common themes/trends that appeared in both focus groups were grouped together and discussed.

6.4 Results

6.4.1 Future Considerations

Participants wanted VRCs to be able to perform all the tasks PRCs could accomplish with some additional features too. The participants said they "*don't want anything less than the current PRC*". The participants agreed that they would prefer to have icons with a picture and text below the image, displaying the channels in a grid format, which allows users to swipe or scroll across the various screens of icons using their fingers. One participant said, "*I really want information displayed in a graphical format.*" Some participants wanted to be able to change the channels quickly using a VRC, by scrolling up and down (instead of across) through all the channels in case users forgot the number of a channel. Participants wanted to tap on the icons to select the

channel (changing the channel on the TV), and display more details about the programmes available (on the VRC), such as the start and ending time of the programme and general information about the programme. Participants wanted shortcuts available to make the changing of channels between advertisements quicker (alternating between channels), rather than going through all the channels to get to the desired one. The participants suggested the shortcut could be a list (history) of the last viewed channels, displayed at the top of the screen, one could then select and switch back to a previously viewed channel and then quickly select the channel they were watching once the advertisements were over.

The participants wanted the channels to be well-grouped with distinct sub-groups in order for the VRC to function well, for example, Movie channels, Home channels, Sports channels. The grid format of icons would allow participants to scroll through all the channels and immediately select the channel and programme they wish to watch. Participants said they wanted to use the swipe gesture to increase or decrease the volume, or to fast forward through programmes (applying to PVR subscribers only). Participants said they wanted a search feature that would allow them to find particular programmes, possibly using multiple categories, for example, searches by genre, actors' names, and sub-categories. The participants said they wanted to search for programmes without scrolling through all the channels to find them, but rather by entering text into the search feature. A participant wanted to know more information about forthcoming attractions with regards to the movies that they may want to watch, giving suggestions to the participant, as well as times and dates of the movies. All participants wanted a QWERTY keypad layout rather than the current keypad layouts on PRC saying "*the current keypad layout is dreadful*." The current keypad layout is in the format of a telephone keypad which requires multi-tapping in order to type a word.

Participants wanted to fully utilise the touchscreen technology and display all written content, channel searching, and reminders relating to the programme, on the VRC rather than on the TV. The reason being that the text on the TV screen covered the show they were watching, and the controls and feedback would be closer to the user. The participants wanted a seamless transition between the remote control functionality and other applications, for example, changing the channels and then switching to the internet, or having a link to external review websites. All participants wanted an easy method of gaining more information about the programme they were watching. One solution was to preview movies before watching them while another was to press and hold the channel icon to display more information. Participants wanted to have a simple VRC layout that would display the most basic and everyday used features on one screen. It was

also very important that participants were allowed to customise the VRC to display their favourite channels. Some participants wanted a list of the last watched channels to be automatically displayed without having to manually set up a list of the favourite channels. These participants wanted the list of 'favourites' to be based on frequency in order to quickly retrieve the channels last watched.

All the participants agreed that if there were too many different types of gestures used to change/switch between screens, participants would forget which ones to use and they would become confused.

6.4.2 Interaction Techniques

All the participants had used different interaction techniques while using various types of touchscreen mobile devices, for example, iPads and smartphones. The most common interaction techniques used were touch gestures:

- Tap
- Double tap
- Swipe (left and right)
- Scroll (up and down)
- Spread and Pinch (zoom in and out)
- Press and Hold
- Press, Hold then Drag

Participants mentioned that they preferred to use a single hand when performing the gestures rather than two hands, and most participants had never used the voice commands. Participants said that "v*oice commands are too unpredictable and inconsistent.*" One of the participants had used a voice command before, however, admitted to "*giving up on it*" as it was "*easier just to tap.*" Participants had concerns about using voice commands while watching TV since there would be noise coming from the TV, "*perhaps there would be problems when trying to activate the voice. Would you need to mute the sound first?*" All participants agreed that a voice command feature would be "*useful for visually impaired people*" and "*for people that shake and can't do taps.*" The participants said that the voice commands would have to be simple, with limited voice options, and nothing sophisticated. One participant said that they did not trust the voice commands, and got irritated if it did not work properly.

All the participants stated that they used the touch gestures in various contexts and in all types of locations: at home, in the office, in the car, at the airport, on the beach, and while walking, to

name a few. One participant did not like to use gestures. Although they were technologically confident with computers, the participant had purchased a touchscreen phone and said, "*I used it for a day and it was the most terrible thing ever.*" The participant said their fingers did not intuitively do the gestures and they would get frustrated. The participant also said they preferred the tactile feedback given by physical buttons.

6.4.3 Design

- Change the channel: Participants wanted to be able to "*flick right to left or left to right to go through the channels*" (swipe gesture) and mentioned that as one swipes from channel to channel, information related to the programme (time, description) should be displayed on the VRC screen. Participants mentioned wanting the option of a keypad to type in the channel numbers. A few participants wanted a list of the channels to scroll up and down through all the selections. Other participants suggested that they would like the channels to be displayed as scrollable icons (pictures with words below them) in a grid format and wanted to press the appropriate icon to change the channel.
- Alternate between channels: Participants suggested that a history of the last two or three channels be displayed on a strip at the top of the screen for participants to easily select one of the last viewed channels. Another option was to have an Alt button available on screen when watching a selected programme on a particular channel, to allow participants to switch back to the channel they were previously viewing. Alternatively, a history list of the last viewed channels, including the day to day channels viewed by participants, be easily accessible on the VRC screen.
- Find a programme to watch on a channel: Participants wanted to be able to type the name of the programme they wanted to watch, on a particular channel, into a search bar. They also wanted the programme details to be displayed when a particular channel icon was selected. Participants wanted to be able to sort/organize the channels to help make the searching easier, for example, they wanted to sort the channels according to how often they viewed them (favourites). One participant mentioned that the most viewed channels could be displayed as the biggest icons and the least used channels could be shown in decreasing sizes. The participants also wanted an up-to-date interactive TV guide timetable to be displayed on the VRC, that allowed them to click on a specific day of the week and for more information to "*pop up"*. Participants wanted all the channels to include information that allowed them to explore and see what programmes were available on the different channels. Participants were adamant about having a well laid out TV guide that included a picture and text, with all the details regarding the show and

actors in it, where appropriate. One participant mentioned wanting an alphabetical list of all the movies so they could scroll through and select a movie, and by pressing and holding the movie label down, find out more information about it.

- Setup reminders: Participants wanted to be able to select a checkbox/icon representing the banner or auto-tune options (reminder options). This would be performed if the participant had pressed and held the programme option down, showing more information and thereby displaying the reminder options. Alternatively, the reminder options would be available as small icons to select when searching for a programme on another channel. Other participants wanted to double tap the label/name of the programme being displayed on a particular channel in order to setup a reminder, and they wanted the reminder to "*bleep*" and make a noise like an alarm clock when the programme was about to start.
- Setup favourite channels: Participants wanted to customise the grid of icons (channels) based on how much they used them, in order to gain quicker access to those features. The participants said they wanted to do this by pressing and holding the channel icons down with a pop-up appearing that allows them to add a channel to the favourites list. An alternative was to select a favourite icon that adds the channel to a favourites list.
- Play recorded programmes from playlist: Participants wanted a multimedia image that allows the users to play the programmes and give participants the ability to interact with the media player, by pressing and moving the scroll icon in the direction they wanted the recorded programme to play. Participants said that they wanted this to appear at the bottom of the screen to allow full control by the participants.
- Record a programme: Participants wanted to press and hold the programme down then select the record option (which pops up similarly to the reminder options), or have a small record icon available on the programme display (when viewing a channel) to allow participants to immediately record live TV (PVR subscribers only). The record option would also need to be available when searching for programmes in the TV guide. Having a record icon available would be a suitable option for the participants.
- Get help: Users wanted to access appropriate help according to the screens they were on (context sensitive help), and wanted the help button/icon to be a question mark or 'help' text. The participants said that the screens should be intuitive enough so that users did not need to use the help functionality.
- Find information about a particular programme: Participants wanted to select (tap) a channel to watch, and if viewers wanted more information about the programme (besides the name and time of the programme) they wanted to press and hold (long press) the channel down for more information to pop up.

- Change the volume: Participants envisioned having a volume scroll bar that they could slide up and down or left to right to alter the volume. One participant suggested having a default/pre-set volume level that participants would usually listen to their programmes. A couple of participants said they wanted 'mute' to be displayed as a button since it was very important when they wanted to quickly silence the TV.
- Specify the language: Participants wanted to access the settings using the main menu through an icon that participants could select. Once a participant selected the icon, a list of the settings options would be available to adjust functionality, for example, the language settings.
- Exit a feature: Participants wanted to exit a pop-up screen by using an 'x' at the top right corner of the pop-up screen, in order to escape the information. However, if the participants wanted to go back to a previous screen, they wanted a back button at the bottom left of the screen. The back button could be written in words or have a back arrow for easy navigation. The participants all revealed that it was important to have a home page button, "*a familiar landing place that is safe*" so that the participants did not feel overwhelmed if they had ventured into an unknown screen.

6.5 Discussion

Participants specified that they wanted VRCs to have all the functionality available to them that is currently on PRCs, with the added functionality suggested by the participants. Participants wanted all the feedback related to information about the programmes to be displayed on the VRC screen instead of the TV screen. A current trend, as mentioned in section 4.3.6, is the use of a secondary screen (touchscreen device) as an extension of the primary screen experience that places all the feedback on a second device and does not display anything on the TV screen (Cesar *et al*., 2008; Courtois & D'heer, 2012). Participants liked that the VRC would be a separate screen from the TV and the users wanted all the searching content, extra information, and reminders to be displayed on the device rather than the TV screen. This is in line with the findings from the CTA (Chapter 5). The placement of icons on the VRC screen allows for easy and quick access to reminders, auto-tune, record, and help, to name a few. The main reason for this was that users did not want their programmes on the TV to be hidden from them while looking for other programmes to watch. An example of this is when users are trying to find out more information about the movie they were watching. Users did not want the TV screen to be covered with written content and they would prefer to read the content on another (second) screen.

Participants were adamant about having the individual channels, help, and volume, displayed as icons, using pictures and words, to make the layout of the UI into a graphical format rather than using lists of words. This is supported by the literature in section 3.7.1. Icons help to create visual interest that serve a greater purpose then just a pretty picture. They use recognition rather than recall to help users easily identify what they are looking for (Klockar *et al*., 2003; Wickens *et al*., 2004). Users of PRCs (during the CTA) were often presented with a channel grid that included lots of text-based channel information presented in one screen on the TV, which made it difficult to quickly select an option based on what they saw. A VRC may overcome this issue by displaying the channels as icons on a second screen (VRC screen), making the selections quicker and easier. Changing the channel to include scrollable icons (up and down), will allow users to browse through a vast amount of channels quickly. Utilizing gestures that users are familiar with (section 3.8), allows them to easily scroll through the channel icons and find the channel they wish to view (Saffer, 2008; Blake, 2012). Allowing users to have various navigation pathways for browsing and specific pursuits enables expert users to quickly change the channel. For example, if they know the channel number they can enter this into the keypad and go directly to the channel, without scrolling through all the others. The icons should contain an image that is easily recognisable, and a label that clearly shows users what channel it is. Recognizable pictures/icons should be used in order for users to instantly remember and select the correct option, as suggested in section 3.6.1 (Nielsen, 1993; Tognazzini, 2007; Heo *et al*., 2009).

A history of the last viewed channels (shortcut) will be used to help users alternate between channels. This shortcut option will enable users to quickly alternate between the channels they are watching, in order to watch two interesting programmes at the same time and make their TV watching time more efficient (Ji *et al*., 2006; Pirker *et al*., 2010). Participants that used the shortcut buttons were noted to use them often to skip past advertisements during the CTA, and found this to be the easiest and quickest way to alternate between the channels. This finding is further supported by section 4.2.2.

Participants wanted to be presented with simple information regarding the channel or programme being watched, and wanted the ability to drill down and get more information by pressing and holding the channel icon down. The underlying requirement was that participants wanted useful information that they could access quickly, which is laid out in an easy to read format with the option of obtaining more information if required; as suggested by Stockbridge and Mughal (2007) and Lee *et al*. (2008). It is important to overcome the problems of PRC layouts and

include all relevant PRC functionality in a skilful way. All participants want a suitable search feature that allows them to search channels by keyword or category in order to find a specific programme to watch. PRCs and digital TV broadcasters currently lack a sophisticated search feature and users have expressed (during the CTA and the brainstorming focus groups) the need to find exactly what they want to watch, without having to scroll through all the unwanted content. Users have limited time and busy lives and they do not want to waste their time searching through content they do not want to watch (Nielsen, 1993). Pan and Ryu (2009) suggested the QWERTY keyboard layout to enter text rather than the standard numeric (telephone) layout that requires multi-tapping to enter alphabetic text. Similarly, users found the multi-tapping keypad to be awkward for alphabetic text, and were more familiar with the QWERTY keypad layout. Section 4.2.8, suggests that cumbersome text entry methods should be avoided.

Norman (1988), Nielsen (1993), Tognazzini (2007), and Shneiderman and Plaisant (2009), all regarded consistency to be of importance in UI design. All aspects of the VRC design must be consistent, for example, the TV guide layout and the way in which programme information is displayed should be laid out consistently. The channels should be well-grouped, for example by genres, such as sports, and movies. Well-grouped information is important in order to have well-constructed user interfaces (Nichols & Myers, 2003). Allowing users to customise their options by setting up their favourite channels, enables them to use their systems more efficiently and effectively since it gives users the power to rearrange the screens according to what they watch most often (Roibás & Sala, 2004; Hess *et al*., 2008). Gill and Perera (2003), and Pirker *et al*. (2010), suggested that personalisation of screens simplifies the interaction and makes the systems easier-to-use for the users.

The multimedia feature to play a recorded programme on the playlist should include a scroll bar to allow users to directly manipulate the position of the programme being viewed, and should make use of known gestures. For example, to fast forward through a programme the user moves the scroll to the right, as suggested in section 3.8 (Blake, 2012). Multimedia buttons will accompany the scroll bar to reiterate the meaning of the scroll bar functionality. Similarly, the volume controller will be portrayed as a scroll bar and placed horizontally across the screen so not to interfere with scrolling of the channels vertically. A mute button will be shown when the volume icon is pressed, to help reduce the amount of space taken up by buttons (Komine *et al*., 2007). The volume bar will always be available, as it was observed, during the CTA, that users

constantly changed the volume, and section 4.2.6 reiterates that frequently used features should be mapped so they are directly accessible by users.

The settings feature should be simple and easy to use, allowing users to specify the language by selecting options from a simple list to reduce the stress placed on a user's memory (Shneiderman & Plaisant, 2009). This is supported by the findings in Chapter 5 and is supported by section 3.6.1 and section 4.2.6. A constant 'exit' or 'x' button should appear on the VRC to allow users to easily escape any task they may be completing, and to allow them to explore the system with confidence knowing they can undo their actions (Stockbridge & Mughal, 2007; Tognazzini, 2007). Similarly, the placement of a 'home' button on screen would give users the opportunity to explore the UI and know that they can get back to a familiar screen. This result is further supported by section 4.2.7.

Participants wanted to use touch gestures to accomplish certain tasks and easily navigate through screens or to select options using natural, intuitive interactions (Saffer, 2008; Blake 2012). The natural touch gestures aid the quick movement through lots of information at a fraction of the time and may improve the efficiency of users, for example, users would not have to press lots of buttons to get to all the channels but rather a scrolling gesture could be used. ISO 9241-11 (1998) emphasizes that a device should be efficient in order to make it more usable to users. The common gestures used by participants were tap, double tap, swipe, scroll, spread and pinch, press and hold, and press, hold and drag. These gestures can be incorporated into the VRC designs in order for natural, familiar and intuitive interactions (section 3.8) to take place between the user and the VRC (Blake, 2012). Participants were concerned that if too many little movements (gestures) were used then users would get confused by all of them. There was a need to have a limited set of gestures that could be applied in different ways according to the screens and icons displayed on the VRC. For example, if a vertical scroll bar icon was placed on the screen then only an up and down scrolling movement should be used to change the position of the scroll.

It should be noted that although the above mentioned features were found to be the most common themes throughout the focus groups, this does not mean that they are of greater importance than themes that were not as frequently mentioned. The participants' input about the possible functionality and designs of current VRC features will be used to formulate guidelines for needed functionality in VRCs. Although many different contributions were received for the completion of different tasks, only one or two methods are used for each function due to their

HCI importance according to the literature and the main themes from the brainstorming focus groups. The designs were selected based on the group perception of how usable the functions would be, given they were implemented in a certain manner. For example, scrollable icons were mentioned by all participants as an easy manner of searching and navigating through many channels in order to select the desired channel.

6.6 Conclusion

This chapter highlighted the functionality users would like to have in a VRC and the design elements as well as gestures that should represent those functions. The discussion of the results was informed by the literature in Chapter 3, Chapter 4, and Chapter 5 (CTA). Together with the brainstorming focus group results, a list of suggested functionality (Table 6.3) was created for the VRC. The list of suggested functionality below will be used in conjunction with the previous chapters' findings in order to better inform the user interface design guidelines, which will in turn guide the VRC prototype design. The brainstorming focus groups uncovered the common gestures users perform when operating touchscreen smartphones. They are: tap, double tap, swipe, scroll, spread and pinch, press and hold, and press, hold and drag. These gestures will be used as the interaction techniques that users will use to interact with the VRC.

Table 6.3: Summary of Suggested Interface functionality to improve UX for VRCs

Activity	Suggested Interface Functionality for VRCs
Change the channel	Scrollable icons up and down Keypad to enter numbers
Alternate between channels	History of last viewed channels functionality
Find a programme to watch	Up-to-date TV guide where programmes can be selected to drill down and show more information Search bar functionality
Setup Reminders	Auto-tune/banner icon available on the screen
Setup favourite channels	Selectable icon that symbolises a favourite channel
Play a recorded programme from playlist	Multimedia feature (scroll bar) can press it and move the position of the scroll with buttons showing play/pause/stop/fast forward/rewind
Record a programme	Record icon available when information is displayed about programmes
Get help	Question mark in the bottom right corner of the screen
Find information about a particular programme	Press and hold the icon for more information to show (pop-up) A selectable link transferring users to an external website
Change the volume	Visual volume scroll bar placed horizontally on the screen so not to interfere with scrolling of channels vertically If volume button is pressed the mute icon appears
Modify the settings - specify the language	Pressing a settings icon, then a list of the available settings appear in a list
Exit a feature (e.g. programme)	Back arrow fixed at the bottom of the screen (inherent in HTC layout) 'x' to at top right corner to close a pop-up screen

Similarly, the functional interface guidelines were created based on users' feedback during the brainstorming focus groups, and will help guide the design of the user interface design guidelines for usable digital TV VRCs (Table 6.4). The VRCs should support these functional interface needs in order to better support the UX.

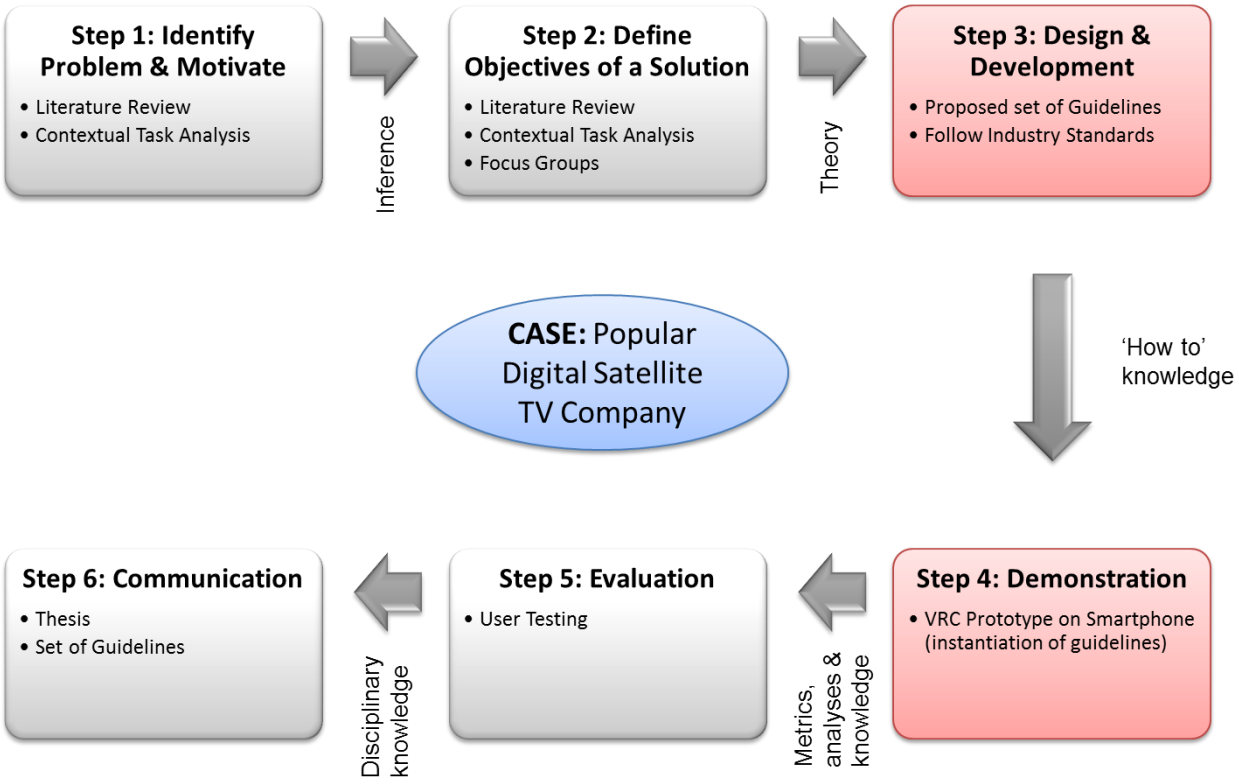
Table 6.4: Functional Interface Guidelines to improve UX

Functional Interface Guidelines	Source
Feedback: Give users the feedback they need on the 'second screen'	
• All feedback to be given on the VRC, for example extra programme information and reminders	
Functionality: Give users simple functionality that allows them to easily interact with the remote control	
• Allow users to customise their channels into a favourites list	
• Provide multiple ways for users to change channels	
• Include a last viewed bar to alternate between multiple channels	
• Include a robust search function	
• Provide a simple manner in which to change settings	Section 6.5
Information: Organise the information shown to users in a logical format	
• Group information by logical genres	
Buttons: Provide users with quick and easy to access buttons	
• Use icons for quick access to functionality, for example channel icons, help, volume	
• Include the QWERTY keyboard for simple text entry	
• Include a mute button for quick volume control	

Chapter 7 Proposed Guidelines

7.1 Introduction

Chapter 7 contributes to step 3 and step 4 of the DSRP model which relates to the design and development of the artefact and demonstration of the guidelines; this is completed through the establishment of a proposed set of user interface design guidelines for creating a usable VRC design on a touchscreen smartphone that will contribute to an enhanced UX.



This purpose of this chapter is to pull together all the design and functional interface guidelines and results from: Chapter 3, Chapter 4, Chapter 5, and Chapter 6; and present a preliminary set of user interface design guidelines (artefact) that will be used to guide the development of a VRC prototype design. This chapter aims to answer the fourth research sub-question, "*What impact do the user interface design features have on the usability and user experience of virtual remote controls?*"

7.2 Method

The guidelines were constructed based on the literature review completed in Chapter 3 and Chapter 4. The proposed user interface design guidelines were grouped into four main sections namely: PUI, LUI, GUI, and NUI (Section 7.3). The results from Chapter 5 and Chapter 6 were

used determine the functionality that should be included in VRCs to support the common tasks (Section 5.6) that users generally perform and overcome the issues with the current PRC functionality. The guidelines from Chapter 6 were used as suggestions of how the functionality should appear graphically on the VRC (Table 6.3). The Android guidelines as well as usability principles were adhered to wherever possible in order to create a usable VRC prototype that was informed by the proposed user interface design guidelines (Nam *et al*., 2003; Android, 2015).

All the above components and information (proposed user interface design guidelines) were used to develop a high fidelity 'in look' VRC prototype. High fidelity prototypes have lots of visual detail and functionality and are close to how the final product will look and feel but are not necessarily fully functional (Snyder, 2003; Coyette, Kieffer & Vanderdonckt, 2007). The high fidelity prototype was created using the Justinmind version 5.1.0 prototyping tool (Justinmind, 2014). Justinmind is a rapid prototyping tool used to build rich interactive wireframes for mobile devices. This tool was chosen since it allowed the researcher to create a VRC prototype with limited backend implementation without having to develop a fully functional application.

The prototype was deployed on an HTC Desire touchscreen phone that used an Android operating system (HTC, 2012). The reasons this phone was used is due to its Android operating system, which is growing rapidly in popularity and accounts for more than half of all smartphone sales in South Africa (Thomas, 2014), as well as the phone's touchscreen capabilities since this technology will be used to overcome problems of PRCs using virtual technology (Tullett, 2012).

7.3 Proposed User Interface Design Guidelines

7.3.1 Physical User Interface Guidelines

The PUI guidelines refer specifically to the feedback that should be given by the instantiated VRC prototype. The researcher has limited control over the hardware that is used for a VRC since this is dictated by the manufacturers however the PUI feedback guidelines should be applied in order to enhance the UX while operating a VRC on a touchscreen smartphone.

7.3.1.1 Feedback

The feedback presented to users should follow the guidelines as presented in Table 7.1 so that users know the system is responding, in a timely manner, to their direct manipulation (gestures) of the functionality on-screen, in a timely manner.

Table 7.1: Feedback Guidelines

Feedback	Source

Guideline 1: Immediate aural, visual or tactile feedback should be given to users
• To show that the system has responded to their actions e.g. button depressions
• More than once to be understood correctly
• Within reasonable time:
  o < 100ms instantly
  o If > 4sec give additional feedback e.g. moving icons
	Section 3.5
	Section 4.4

7.3.2 Logical User Interface Guidelines

The LUI guidelines refer specifically to the logical aspects of how the information architecture (IA) (menus), navigation structure, and findability of functions are developed through the instantiated VRC prototype, to enhance the UX.

7.3.2.1 Menu

The menus for usable VRCs should be well organised and have a well-structured IA that presents the menus correctly to users so that they can complete tasks with ease, and find what they need to quickly (Table 7.2).

Table 7.2: Menus Guidelines

Menus	Source
Guideline 2: Menus should be well-structured and well-grouped • Use the 7± 2 rule for menu items • Well-defined menu and icon labels • Frequently used items first on the menu list • Menus should be simple with shallow levels (hierarchical structures) for easy navigation	Section 3.6.1 Section 4.4

7.3.2.2 Wording

The guidelines for wording should be used to create consistent and familiar terminology that users can easily understand (Table 7.3). The labels should be clear, simple, and well-defined so that users can orientate themselves through the various screens.

Table 7.3: Wording Guidelines

Wording	Source
Guideline 3: Provide users with familiar, non-technical language (wording) • Clear and simple UI titles • Consistent wording • Make use of descriptive wording that is simple and clear to users • Avoid technical jargon • Use correct semantics for words accompanying buttons (icons) • Label the key word first for labels and menu items	Section 3.6.2 Section 4.4
Guideline 4: Error messages give users information about what went wrong	

• State which error occurred and give constructive help • Use plain language with no technical jargon • Allow for sufficient reading time	

7.3.2.3 Navigation

The guidelines for navigation should influence the way users gain access to certain functionality on VRCs, using various routes (Table 7.4). The use of simple navigation that allows users to reverse their actions and explore the UI may help users to have an enjoyable UX.

Table 7.4: Navigation Guidelines

Navigation	Source
Guideline 5: Navigation must follow a consistent structure and flow that allows users to explore the interface	
• Simple navigation that is not cumbersome • Real-world conventions/metaphors to allow the information to be logical and natural • Use recognition rather than recall to limit stress placed on users memory • Include undo, back or cancel buttons for easy reversal of actions • Provide quick access (shortcut buttons) to frequently used features e.g. home button • Provide unchanging visual cues • Use historical navigation for previously viewed pages • Place frequently used buttons in easy to access places	Section 3.6.1 Section 4.4

7.3.3 Graphical User Interface Guidelines

The GUI guidelines refer specifically to the visual (graphical) features/functionality that is presented to users to allow them to perform tasks. The guidelines should shape the look and feel for the instantiated VRC prototype GUI, to enhance the UX.

7.3.3.1 Mental Models

The guidelines for mental models should allow users to instantaneously understand system (VRC) processes and draw on their prior experiences, so to have an enjoyable UX (Table 7.5).

Table 7.5: Mental Models Guidelines

Mental Models	Source
Guideline 6: Features and functionality should be aligned with user mental models	
• Use icons for menu items where possible • Use metaphors to help users instantly understand processes • Use metaphors consistently • Follow user mental models to correctly group functionality • Group buttons across different screens for situation dependent variables • Use the standard numeric (telephone) layout for numeric entry	Section 3.7.4 Section 3.7.5 Section 4.4

7.3.3.2 Buttons

The button guidelines should influence the aesthetics and clickable areas of the buttons, including the shape, size, and placement of buttons in relation to other information (Table 7.6).

Table 7.6: Button Guidelines

Buttons	Source
Guideline 7: Buttons (icons) should clearly communicate the content they represent	
• Button sizes between 7mm and 10mm • Keep the number of buttons to a minimum • Use large buttons for important features • Use uncomplicated, simple buttons • Use varied shape buttons, for example squares and circles • Use colours and appealing designs to make buttons more attractive • Hide or remove non-essential buttons from screens • Avoid cumbersome text entry methods. A quick and simple text entry method is needed	Section 3.7.1 Section 3.7.2 Section 4.4
Guideline 8: Button placement and positioning should be consistent that allows for quick thumb navigation	
• Use good spacing between buttons • Left position on screen for smaller buttons • Right position on screen is more suitable to buttons • Frequently used buttons should be placed in the centre • Lower right areas on screen are harder to reach	

7.3.3.3 Screen Display

The screen display guidelines will affect the look and feel of the VRC functionality and layout of all the components. In particular, the screen display guidelines recommend large font sizes, colours with the correct connotations, anticipating users' needs and wants, and allowing them to easily learn the system and orientate themselves using all the visual cues (Table 7.7).

Table 7.7: Screen Display Guidelines

Screen Display	Source
Guideline 9: The user interface screen display should be kept simple, consistent and uncluttered	
• Visually attractive and balance simplicity and functionality • Ensure permanent labels are used • Give good default designs for a single coherent experience • Ensure correct input objects are used, for example a dropdown • Include prominent 'signposts' that assist users with easy navigation • Provide visual cues for scroll bars • Use a combination of horizontal swipes and vertical scrolling for navigation • Use a simple layout that is flexible to changes and updates • Design a stylish, intuitive UI layout that is easy to use and learn	Section 3.7.3 Section 3.7.4 Section 3.7.5 Section 4.4
Guideline 10: Contrasting colours and large font sizes should be used to improve legibility between labels and the background colour	
• Include a readable typeface and large font size • Colours should be used consistently for buttons and labels • Keep colours consistent with those in the real world, for example red for a power	

button • Make use of brightness, redundant signals, location and shape, to help colour deficient users	

7.3.3.4 Graphical Principles

The guidelines for the graphical principles aim to have all functionality on the VRC mapped correctly, according to their usage, so that users can fully understand how to use the features on screen (Table 7.8). Visually the functionality has to be accurate and the items need to show some affordance so that users know they are able to select or manipulate the specific functionality.

Table 7.8: Graphical Principles Guidelines

Graphical Principles	Source
Guideline 11: Consistent graphical principles and grouping should be applied	
• Minimise the number of screens and button presses	
• Clearly map buttons in positions conducive to their functionality	

• Consistency should be employed throughout the GUI
  ○ Through user behaviour
  ○ Invisible structures
  ○ Be visually inconsistent when features are different
  ○ Be visually consistent when features are the same
  ○ Predicting user expectations
	Section 3.7.4
	Section 3.7.5
	Section 4.4

• Elements displayed closer together are grouped as one whole	
• Elements that have similar attributes are grouped together	
• Users prefer greater symmetry	

7.3.4 Natural User Interface Guidelines

The NUI guidelines refer specifically to the manner in which users interact with the GUI of a device in order to complete their tasks.

7.3.4.1 Gestural Interfaces

The gestural interfaces should employ natural actions familiar to users so that they can carry out the tasks they wish to complete (Table 7.9). The most frequently used gestures, as suggested during the brainstorming focus groups are: tap; double tap; swipe; scroll; spread and pinch; press and hold; and press, hold and drag.

Table 7.9: Gestural Interface Guidelines

Gestural Interfaces	Source
Guideline 12: Gestures used should be natural actions that users are familiar with in order to increase their interaction • Use multiple indicators to show what actions can be taken • Rapid instant responses to touch • Appropriate gestures for different situations, for example tap, tap and hold, pinch, swipe, and scroll • Use playful engaging gestures that allow for exploration of the system	Section 3.8 Section 6.5

7.3.5 Functional Interface Guidelines

The functional interface guidelines pertain specifically to the feedback that was given during the CTA (Chapter 5) and brainstorming focus groups (Chapter 6). These 'functions' were noted from the observations and mentioned by users to either be useful to accomplish common tasks missing from current PRCs, or issues that needed to be addressed in the VRC design (Table 7.10). The user interface needs to support these functional interface guidelines in order to improve users' experiences with VRCs.

Table 7.10: Functional Interface Guidelines

Functional Interface Guidelines	Source
Feedback **Guideline 13:** Give users appropriate feedback on the expected interface • Display all feedback on second screen (not the TV), for example extra programme information and reminders • Include visual or aural banner and auto-tune reminders	
Functionality **Guideline 14:** Give users simple functionality that allows them to easily interact with the remote control • Allow users to customise their channels into a favourites list • Include a robust search function • Give users context sensitive help • Settings should be simple and uncomplicated • Provide users with a manner of alternating between multiple channels • Provide multiple ways for users to change channels	Section 5.5 Section 6.5
Information **Guideline 15:** Organise the information shown to users in a logical format • Provide users with a TV guide that gives them enough information about the TV programmes • Give users the ability to acquire additional information from external sources (internet) • Provide users with a simple way to access more information, for example an information button • Group information by logical genres	
Buttons	

Guideline 16: Provide users with quick and easy to access buttons

- Use shortcut buttons for frequently used functions
- Allow for numeric input to change channels quickly
- Make the volume control easily accessible, include a mute button for quick volume control
- Most buttons should only have one purpose
- Use icons for quick access to functionality, for example channel icons, help, volume
- Include the QWERTY keyboard for simple text entry

7.4 Applying the Proposed User Interface Design Guidelines to a VRC Prototype

The following section shows how the proposed UI design and functional guidelines are used to guide the design and functionality of the VRC prototype. This section uses the findings from Chapter 3 and Chapter 4 to inform the rules regarding the layout, and overall look and feel of the VRC prototype. Chapter 5 (Table 5.8) and Chapter 6 (Table 6.3 and Table 6.4) were used to better inform the functionality of the VRC prototype. The CTA and brainstorming focus groups generated functional requirements that inform the VRC prototype design. This functionality should allow users to complete the common tasks they generally perform and should attempt to overcome the issues users experienced when completing more infrequent tasks.

A hub and spoke design was used to create the VRC (Figure 7.1). The hub and spoke pattern gives users a central index from which they are able to navigate out (Oviatt *et al.*, 2000; McVicar, 2012). This pattern limits users from navigating between spokes (four outer rectangles) but rather forces users to return to the hub instead (central rectangle). This pattern is becoming more prevalent in the mobile landscape since users are generally focused on one task, and the limitations of the form factor of mobile devices can make global navigation more difficult to use (McVicar, 2012). This pattern allows for focus on one section at a time with self-contained, simple UIs to help prevent errors (Tidwell, 2005).

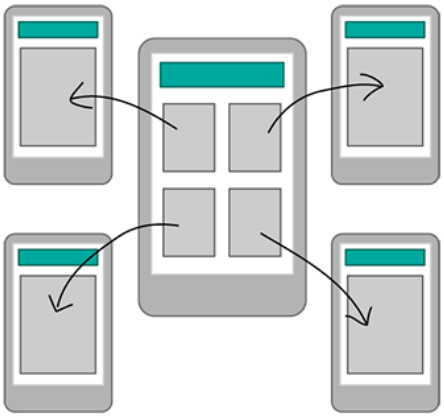


Figure 7.1: Hub and Spoke Design (McVicar, 2012)

7.4.1 Homepage

The homepage is the first screen that the user will see when opening the VRC. It shows five buttons that are labelled, which allows users to navigate to the appropriate sections of the VRC (Figure 7.2). There is a power button in the top right-hand corner of all screens to allow users to turn the VRC off at any point. A volume scroll bar is also available at the bottom of the screen to allow users to change the volume of what they are watching on the TV (this is always available) as suggested by guideline 16 (Table 7.10). A question mark, that represents the help button, is shown in the bottom right-hand corner to give user access to content specific help, as indicated by guideline 14 (Table 7.10).

Figure 7.2 uses well-defined menu labels, clear and simple UI titles, as suggested by guideline 2 (Table 7.2); as well as familiar terminologies for the VRC environment indicated in guideline 3 (Table 7.3). These are shown through the labels on the grey buttons, for example, Favourites or TV Guide. This screen shows simple navigation that is not cumbersome (spoke - five possible selections to choose from) and uses real world conventions such as the volume icon or the power button icon to allow the information to be logical and natural for the user, as proposed by guideline 5 (Table 7.4). The button sizes are at least bigger than 7mm and they clearly communicate what content they represent as suggested by guideline 7 (Table 7.6). For example, TV guide clearly represents the guide information for the programmes that will be on various channels. The use of large buttons, that are uncomplicated and well-spaced, ensures that buttons are not accidently pressed as suggested by guideline 8 (Table 7.6). The number of buttons was kept to a minimum per screen in order to keep the UI simple, intuitive, and uncluttered as suggested by guideline 7 (Table 7.6). Buttons were placed around the screen so to allow for thumb navigation and easy access to functionality, as suggested in guideline 8 (Table 7.6).

Colours were kept consistent with those in the real world, for example, red for the power button as suggested by guideline 5 (Table 7.4).

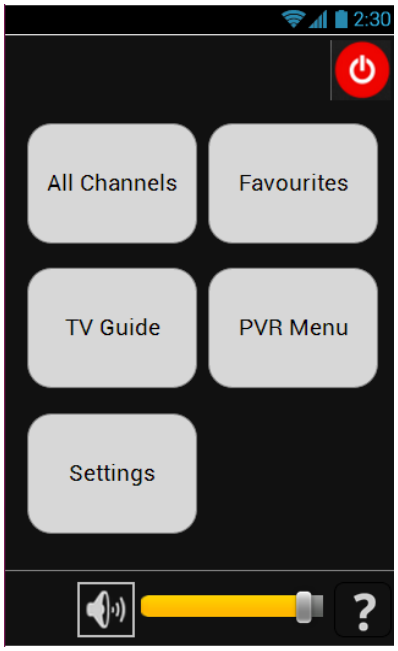


Figure 7.2: Homepage (hub) showing other 'spoke' areas of VRC

7.4.2 All Channels

When users select the All Channels button on the homepage they will navigate to Figure 7.3-A which shows quick access routes to frequently used features (guideline 5 Table 7.4). For example TV and NumPad (number pad). This screen shows the home button in the top left-hand corner which will allow users to navigate back to the homepage (hub) and a 'numpad' that allows users to insert channel numbers into a numeric keypad. There are two tabs, one labelled TV and the other Music. These tabs allow users to alternate between the TV channels and the audio channels (which include the non-visual radio and music channels). The channels are grouped under various headings (guideline 15 Table 7.10) such as General Entertainment, and the channels are represented by icons with channel numbers. A last viewed bar is directly below the channel icons. This bar displays which channels have been navigated to recently as suggested by guideline 14 (Table 7.10).

The use of the correct semantics for words accompanying buttons/icons, for example NumPad, places the word 'Num' before pad which indicates immediately that numbers are involved and the icon further demonstrates what users can access when they press the button, as suggested in guideline 3 (Table 7.3). A consistent structure and flow are used throughout the VRC prototype by providing unchanging visual cues and prominent signposts for easy navigation, as suggested

by guideline 9 (Table 7.7); for example, the home button. The home button is also a quick access route back to the main screen to allow users to navigate throughout the prototype. Historical navigation is provided by the 'last viewed' functionality which should help users see what items they previously viewed and to navigate to those choices, as suggested by guideline 5 (Table 7.4). Icons are used to represent the volume controller and the power button which are consistently placed on the screen to assist users with learning how to use the functionality from screen to screen, as suggested by guideline 11 (Table 7.8). Functional groupings like general entertainment, were used across different screens for situation dependent variations of buttons to try increase the usability of the VRC, as suggested by guideline 2 (Table 7.2). The Gestalt Principles describe that when elements are grouped close together, they are perceived as one whole, which is similar for the channel logos that are grouped together underneath the general entertainment heading, as suggested by guideline 11 (Table 7.8). Users can correctly assume that the channels form part of the same grouping, i.e. general entertainment. A large typeface and font size were used to make the labels legible to users, as well as contrasting colours (black on grey) to help increase the legibility of the text, as suggested by guideline 10 (Table 7.7), for example, the TV and Music text. The grid format of all the channels provides a symmetry that is visually attractive, as suggested in guideline 11 (Table 7.8).

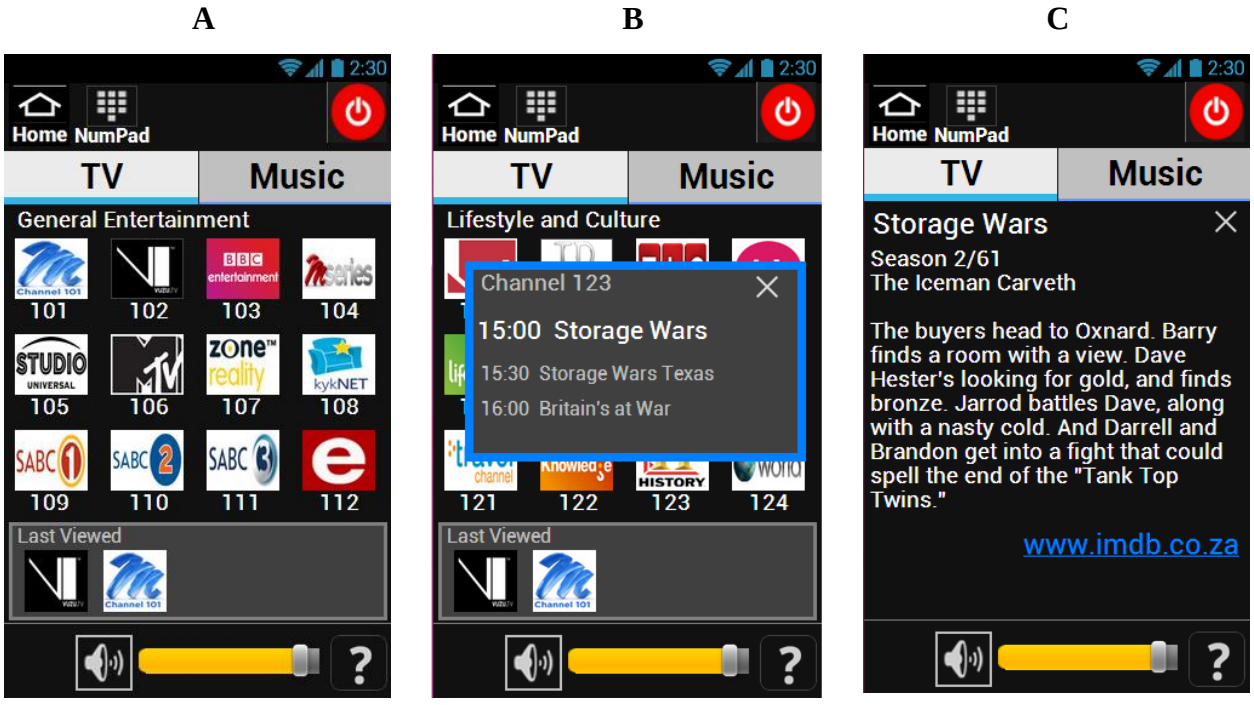


Figure 7.3: All Channels. A) A grid of TV channel icons; B) Channel information showing upcoming programmes; C) Detailed programme information.

7.4.3 Channel Information

When the user clicks a channel, for example, channel 123, they will be presented with a popup screen showing information about the upcoming programmes and the programme times on the particular channel (Figure 7.3-B). Three items are listed at a time so that users are not overwhelmed with too much information, as suggested by guideline 15 (Table 7.10). This information is displayed on the smartphone VRC rather than the TV screen so not to block users' viewing of their programme, as suggested by guideline 13 (Table 7.10). The screen shows a popup with upcoming channel information. The users can cancel the popup through the use of an 'x' in the top right hand corner so that the users can reverse their actions and explore the interfaces, as suggested by guideline 5 (Table 7.4).

7.4.4 Detailed Programme Information

A user must select the programme name within the channel popup in order see detailed programme information Figure 7.3-C). The detailed programme information gives users a synopsis about the programme that is shown on the VRC second screen, as well as an external link to allow users to source more information about the programme, as suggested by guideline 15 (Table 7.10). An external website link, to an online database for information on movies and TV programmes (www.imdb.co.za), is included on the information page so that users can find extra information about the programme immediately.

7.4.5 Number Pad

When a user clicks on the 'NumPad' at the top of the screen, users are presented with a number pad (Figure 7.4) that allows them to type in the channel number they wish to navigate to, as suggested by guideline 16 (Table 7.10). As a user types the numbers, they will appear in the white textbox at the top of the screen and when a user presses 'Go' the channel on the TV should be changed. The number pad uses a standard numeric (telephone) layout for numeric entry, to type in channel numbers. This draws on users' pre-existing mental models, as most users have experience using a cell phone number pad which generally uses the same layout, as suggested by guideline 6 (Table 7.5). A good default design for the number pad is used so that the majority of users can use this functionality and have a single coherent experience, as suggested by guideline 9 (Table 7.7). The 'Go' button uses the colour green, which has a positive connotation, and differentiates this button from the others which draws attention to it. The text further explains what action can be taken when pressing the button, as suggested by guideline 10 (Table 7.7).

Figure 7.4: Number pad showing numeric buttons

7.4.6 TV Guide

The TV guide button on the homepage would be selected to navigate to this screen (Figure 7.5-A). The TV guide is the equivalent of what the TV guide magazine may have in it. The three tabs are labelled TV guide, news, and weather. TV guide will show users more information about the channels and programmes, as suggested by guideline 15 (Table 7.10). News and weather are functionality currently available on the popular digital broadcaster's decoder but are out of scope for this dissertation. Directly below the TV guide tab are the dates for the week. If a user navigates to 'Today', they will see a list of channels and the time and names of the programmes that will be on those channels. There is a star next to each channel which allows users to add the channels as their favourites.

The search textbox allows users to search for programmes within the TV guide, as suggested by guideline 14 (Table 7.10). The use of colourful channel logos was so that users would immediately recognise what channel is being displayed, as well as to make the designs appealing and the UI more attractive, as suggested by guideline 5 (Table 7.4) and guideline 6 (Table 7.5). If changes need to be made to the layout of the VRC, it is flexible enough to accommodate for any updates since all the items are 'virtual' and not physically inflexible. A fine balance is maintained between simplicity, in that there are a limited amount of channels and information shown per screen, and the functionality so that users can switch between different days of the week. The question mark on the bottom right hand corner is a metaphor that is used consistently throughout the prototype. It is used to represent the help functionality and is consistently placed

in the same position on each screen, as suggested by guideline 6 (Table 7.5) and guideline 8 (Table 7.6). The TV guide button is represented with a thick blue line underneath it that indicates the button is selected (feedback given), in comparison to the button next to it that has a fine blue line, as suggested by guideline 1 (Table 7.1). It is important that the correct input objects are used on screen, for example, the textbox allows users to input text they want to search for. When the text box next to the search button is selected the smartphone's native (built in) keyboard should appear on screen giving users a quick entry method (that is not cumbersome) to type in text and search for the items they are looking for, as suggested by guideline 7 (Table 7.6).

A **B**

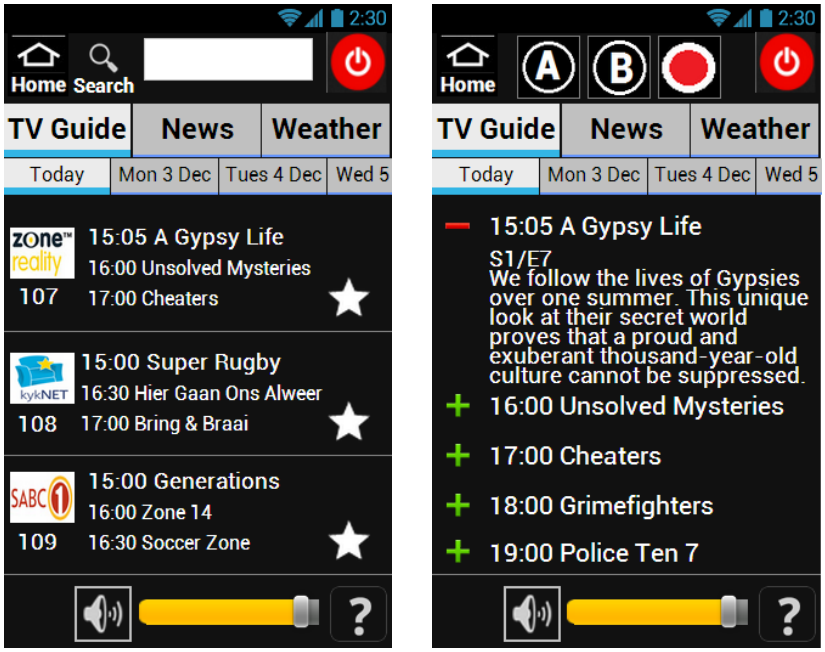


Figure 7.5: TV guide. A) TV Guide listing showing channels and programmes on particular days of the week; B) Programme information showing red minus and green plus icons.

7.4.7 Programme Information

Selecting a programme in Figure 7.5-B shows the programme information and the three buttons at the top of the screen, A (autotune), B (banner), and the record button. These buttons were not essential to the information shown in Figure 7.5-A and were hidden to make the screen less cluttered (hide complex functionality from novice users), as suggested by guideline 7 (Table 7.6). A green plus and red minus symbol was used to represent the expansion and contraction of the information for each programme shown. This is a commonly used symbol in many systems and it draws on users' mental models so that they can immediately understand how to use the functionality, as suggested by guideline 6 (Table 7.5). Varied shaped buttons, for example, a round record button and a screen home button, were used to make them distinguishable and to make them more recognisable, as suggested by guideline 7 (Table 7.6).

7.4.8 Bookmark Favourite

A user would bookmark their favourite channel by selecting the star next to the channel listing, within the TV guide, as suggested by guideline 14 (Table 7.10). Figure 7.6-A shows the TV guide listing with a favourites star selected. A star was used to mimic many internet browsers, as suggested by guideline 6 (Table 7.5), for example, Chrome that uses the star to bookmark a page. In the same way a star was used in this design to 'remember' a selection so that it can be easily accessed later (Google Chrome, 2015).

A **B**

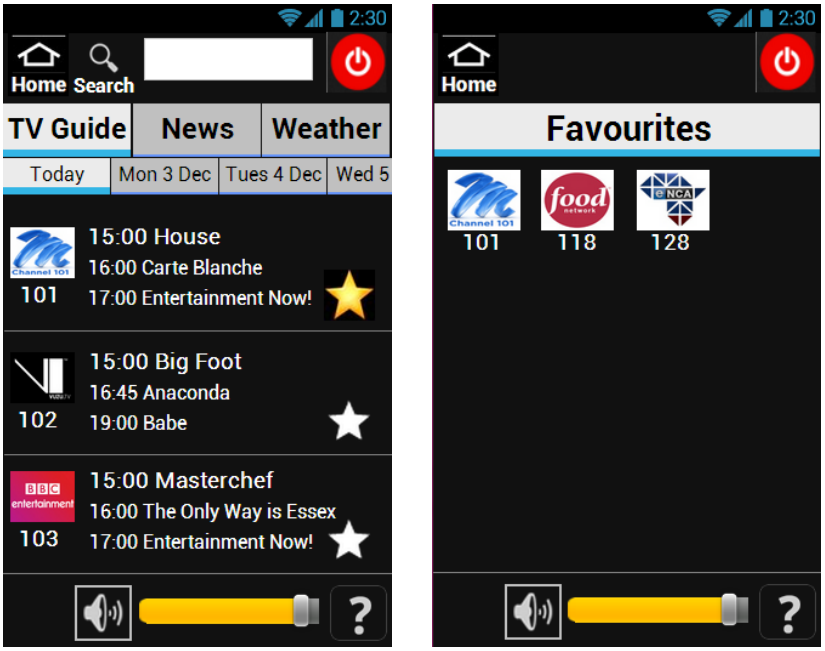


Figure 7.6: Favourites. A) TV guide showing channel 101 bookmarked as a favourite; B) Favourites listings page.

7.4.9 Favourites

A user would select the Favourites button on the homepage to navigate to this screen, which shows the channels that users have bookmarked as their favourites. Figure 7.6-B uses a clear, simple label at the top to indicate what screen the user is on, favourites. The label is descriptive and a common, familiar term to users so that they can immediately understand what the screen represents, as suggested by guideline 3 (Table 7.3). The screen is designed to encompass a minimalistic, stylish look and feel that is visually attractive to users, through the use of clean lines and the dark high contrast background, as suggested by guideline 9 and guideline 10 (Table 7.7).

7.4.10 Personal Video Recorder Menu

A user would select PVR menu on the homepage to navigate to this screen (Figure 7.7-A). The PVR menu shows three tabs: playlist stores all the previously recorded programmes setup by the

user; catch-up is the preloaded content that a user can watch; and movie rental allows users to rent a movie (out of scope). Within the catch-up menu is the listing of available programmes with a play icon next to them. This screen uses the play button next to the programme listings to indicate that users can play the content, thereby helping the users to instantly understand the processes of this screen, as suggested by guideline 12 (Table 7.9).

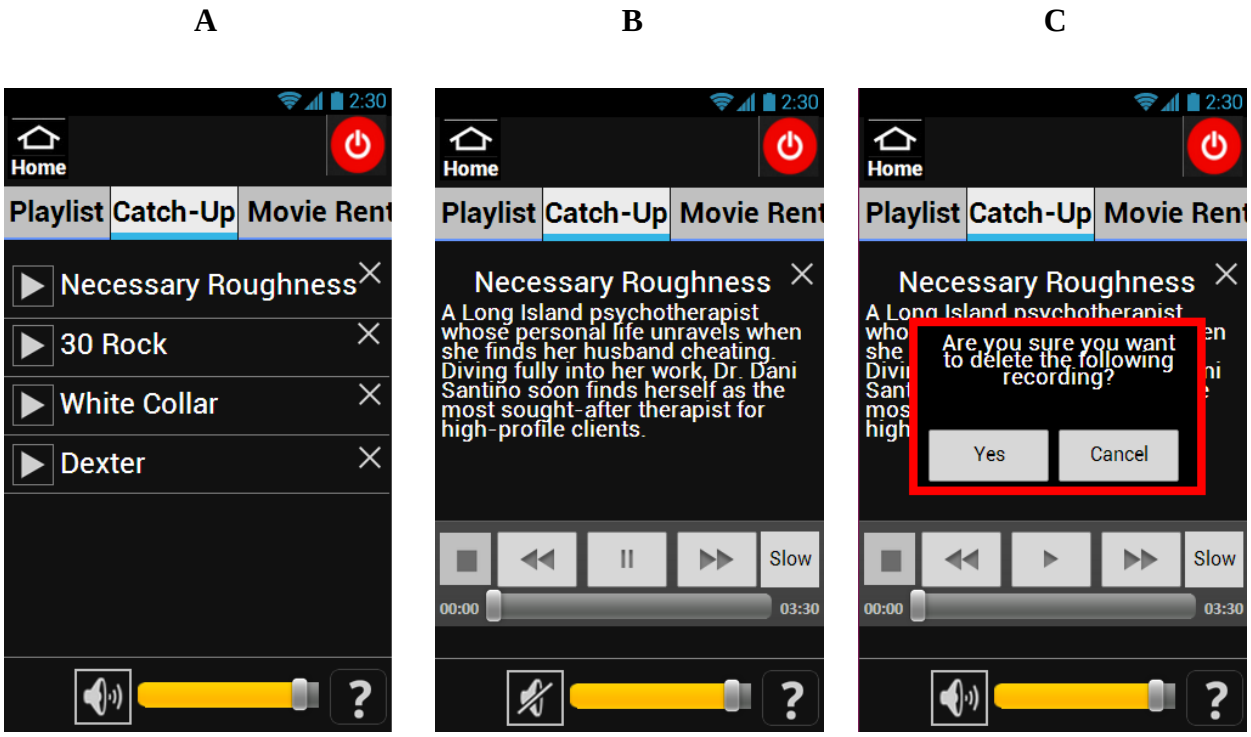


Figure 7.7: PVR Menu. A) PVR menu showing a listing of programmes within the catch-up menu; B) A recorded programme being played showing the volume has been muted; C) Deleting a recorded programme showing a confirmation popup box.

7.4.11 Recorded Programme Viewing

If a user selects an item off the catch-up list, they will find more details about the programme that they wish to play (Figure 7.7-B). A synopsis is shown, along with a multimedia player with buttons that allow users to stop, rewind, pause/play, fast-forward, and play the programme in slow motion, as well as a scroll bar that a user can move quickly to a specific position in the programme, as suggested by guideline 12 (Table 7.9). The screen also shows that the volume has been muted, by pressing on the volume icon. The change of the volume icon to a 'muted' state is shown by a line through the volume icon. This is a global symbol that is used by many for volume and mute, as suggested by guideline 6 (Table 7.5).

7.4.12 Deleting a Recorded Programme

If a user selects the 'X', it will allow them to delete the programme and a popup appears asking for confirmation to delete the programme (Figure 7.7-C). The confirmation popup makes use of

brightness (red border) to show users that they are about to delete their recording, as suggested by guideline 1 (Table 7.1) and guideline 4 (Table 7.3). The popup is well-defined by a bold red border. It is in the centre of the screen to draw the user's focus and makes it impossible to move on before an action, 'yes' or 'cancel' is taken, as suggested by guideline 10 (Table 7.7). This enables all users regardless of their colour deficiencies to clearly notice the 'warning' message.

7.4.13 Settings

A user will select the settings button on the homepage in order to navigate to this screen (Figure 7.8-A). Users are presented with a list of alphabetised settings options. When 'language' is selected a user will be redirected to the language settings, and if they select an option the selected area will turn blue (Figure 7.8-B). Figure 7.8-A uses a simple list of items that has a shallow structure, to allow users to easily navigate between the settings options, as suggested by guideline 2 (Table 7.2). The listed items are well-defined, for example, parental control and language, so that users can understand what action they can take within each, as suggested by guideline 14 (Table 7.10). A user that presses the language option from Figure 7.8-A is presented with three options in Figure 7.8-B, which follows the 7±2 rule for menu structures. Figure 7.8-B displays the different language options that users can select. The use of recognition, rather than recall is used to limit the load placed on users' memory by showing the options upfront, as suggested by guideline 5 (Table 7.4). The key word, or type of language, is listed first so that users know the languages they can select (if another language was available, for example, Afrikaans). The use of shallow menu structures minimises the number of screens and buttons users have to press, since the options are kept to the bare minimum.

A **B**

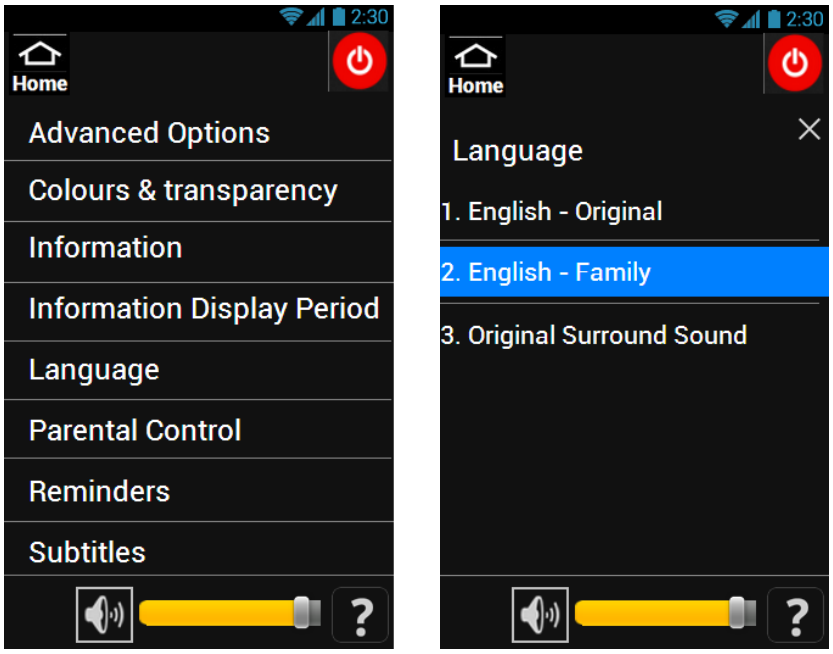


Figure 7.8: Settings. A) List of alphabetised settings options; B) List of language settings options.

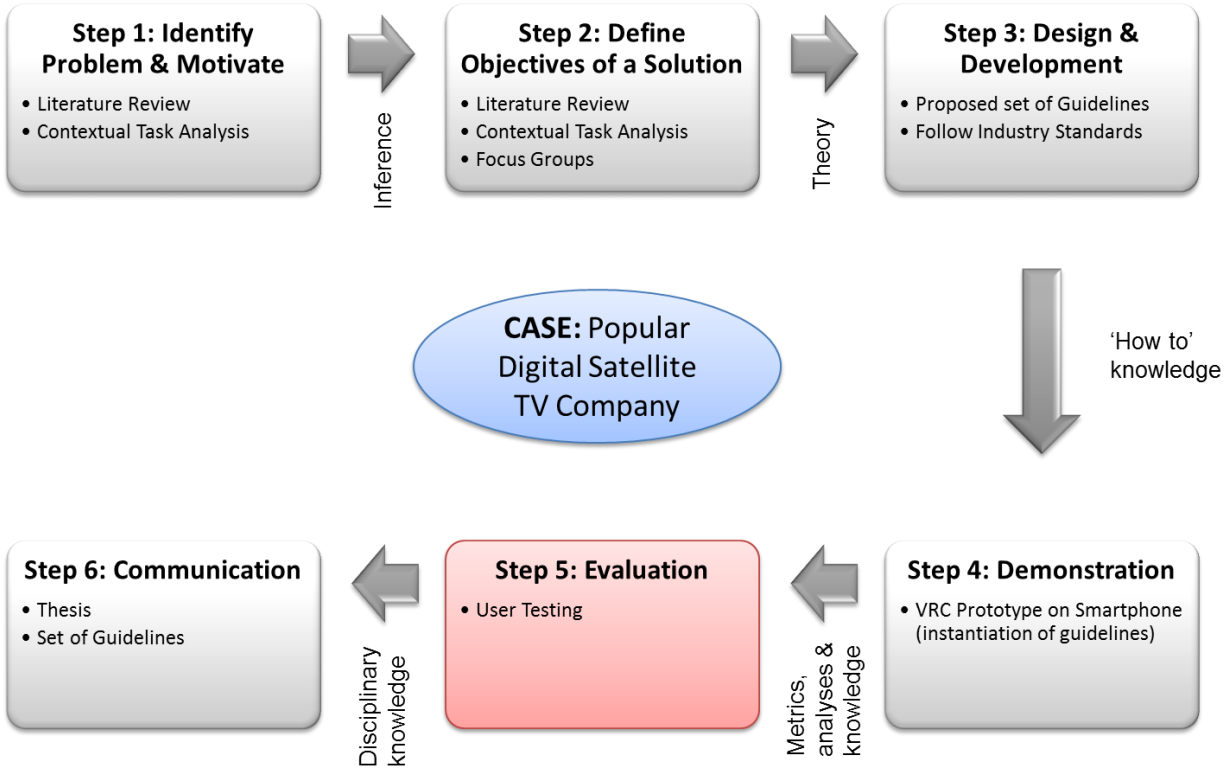
7.5 Conclusion

This chapter presented the developed set of user interface design guidelines, which included the GUI, LUI, PUI, and functional interface, that were generated from the previous chapters; namely Chapter 3, Chapter 4, Chapter 5, and Chapter 6. The sixteen guidelines were successfully demonstrated through the creation of a high-fidelity VRC prototype that applied the proposed set of user interface design guidelines.

Chapter 8 Prototype Evaluation

8.1 Introduction

Chapter 8 contributes to step 5 of the DSRP model, which relates to the evaluation of the proposed user interface design guidelines through the user testing of the instantiated VRC prototype.



The purpose of this chapter is to evaluate the usability of the VRC prototype (based on the guidelines) and gain insight into the user experiences of participants whilst using a VRC prototype in the TV watching context, in order to validate the researcher's application of the proposed set of preliminary user interface design guidelines (Section 7.3). This chapter discusses the usability testing method, the procedures adhered to, as well as the results obtained from the evaluation. The results are analysed and conclusions drawn. Usability testing involves observing users while they perform tasks with hardware or software systems (Kuniavsky, 2003). One-on-one usability tests quickly reveal information about how people use prototypes and assist researchers in the identification of usability problems.

8.2 Rationale for Technique

Waterson, Landay and Matthews (2002) performed a pilot usability test requiring users to find safety, and local dealer information for a Nissan Sentra using the internet on a wireless personal digital assistant (PDA). Waterson *et al.* used the WebQuilt System, a proxy based clickstream

logging and visualisation system, and found that clickstreams and remote testing were good at finding usability issues related to the web content displayed on mobile devices, but that this methodology was a poor substitute for finding usability issues with the device itself.

Koskela and Väänänen-Vainio-Mattila (2004) evaluated the usability of three UIs: a PC, mobile phone and media terminal, for smart home environments using heuristic analysis and usability tests. The results indicated that users wanted the smart home devices to be mobile, constantly turned on, and always accessible (from inside and outside the house), however, they were concerned about the reliability of controlling the appliances from a distance. The usability tests therefore enabled the authors to make minor changes to the UIs of the three devices and to understand the design considerations to improve upon. Similarly Wisniewski (2011) discussed usability testing of library information systems on mobile devices, and said that usability should be the focus for every stage of design. Wisniewski suggested that usability testing should be performed on multiple hardware configurations and by a wide variety of users, although emulators, simulators and lab testing could be useful Wisniewski said they should not replace usability evaluation by real people in real life situations. Racadio, Rose and Boyd (2012) used field studies to design and evaluate the mobile experiences of customers, using the transit services of a business called Sound Transit. Racadio *et al*. performed the user testing on mobile phones, in real usage contexts, and gained a reliable representation of the users' mobile user experience, and collected feedback about the product in its natural usage setting. In contrast to the above studies, Kaikkonen *et al*. (2005) compared the usability testing of the user interfaces of mobile applications in a laboratory environment versus field testing. They found no differences between the number of usability problems that occurred in the two test settings. Despite the lack of differences between the testing environments, the researcher decided to perform the user testing within the users' natural TV watching environments, in order to capture sincere user experiences and to record the usability issues faced by the participants. The above mentioned studies helped to structure the user testing for this research, which aimed to gather real life experiences from users using the VRC on a touchscreen smartphone, in a natural environment, in order to get the most accurate and truthful usability results.

Rosario, Ascher and Cunningham (2012) employed usability testing, for their paper prototypes, when redesigning a Health Sciences Library's mobile site. The needs assessment and usability testing informed Rosario *et al*. about the design of the site to facilitate task completion, as well as the enhancements and improvements to the original site design, based on the user feedback. This research, therefore, made use of the needs assessment and usability testing to gather vital

feedback from users, and to contribute to the design process to make the prototype more usable in order to facilitate the completion of user tasks.

All of the above authors used similar processes to carry out their user testing. This helped to inform the researcher on techniques to use to gather the most valuable information from users to obtain useful results. Usability testing was used in this research to see if the application of the proposed user interface design guidelines could assist in creating a usable VRC prototype, and contribute to an enhanced UX. The usability testing allowed participants to perform similar tasks to those revealed during the CTA, in order to identify possible usability issues with the UI designs, which were informed by the proposed set of user interface design guidelines. Usability testing was used to explore the problems participants discovered when performing VRC tasks, and took into consideration participants' comments about the features they enjoyed and disliked.

A few of the advantages of performing usability tests are that design flaws and other issues may be revealed by participants during the tests, and the researcher can probe the participants further about the problems they may be experiencing in order to better understand their user experience of the prototype. More than eighty percent of the usability problems can be found with using only five users as suggested by Nielsen (1993). The disadvantage of usability testing is that not all the problems will be found with a small sample of users.

The main objective of the usability testing in this research is:

- to establish if the application of the user interface design guidelines, based on previous chapters (Chapter 3, Chapter 4, Chapter 5 and Chapter 6), to the VRC prototype could assist in creating a usable prototype, and contribute to an enhanced UX.

8.3 Method

The usability testing was guided by the methodologies stated in section 8.2 and is further supported by the methodologies conveyed in Kuniavsky (2003), Snyder (2003), and Tullis and Albert (2008).

8.3.1 Participants

The age groups used in the study were based on the popular digital satellite TV provider's statistics. The age groups for the subscribers have been divided into six categories as shown in Table 8.1 (Wentzel, 2011). It was concluded that having at least two participants per age category (at least 1 participant in each category for the categories 50-60+) would represent a

stratified convenience sample needed for the research. The same convenience sampling technique that was used in Chapter 5, and Chapter 6, was also applied in this chapter (Tullis & Albert, 2008).

Table 8.1: Population Sample (Wentzel, 2011)

Age Category	Representative base	Participants
15-19	12%	Out of scope
20-29	23%	2
30-39	23%	2
40-49	18%	1 or 2
50-59	12%	1 or more
60+	12%	1 or more

The sample group of seven participants asked to complete the usability testing was different to the sample group used in Chapter 5, and Chapter 6. The usability tests were employed to help evaluate the applied set of user interface design guidelines for an enhanced VRC UX (Chapter 7), and to identify any usability issues while using the VRC prototype that may better inform the proposed guidelines. Tullis and Albert (2008) suggested that between six and eight participants should be used for usability testing, as the most significant usability findings will be observed by at least the first six participants. Kuniavsky (2003) echoed this sentiment. Due to the limited number of participants in the usability study, the results could not be generalized to the entire population. However, the data collected can be used to improve the proposed set of user interface design guidelines (Eronen, 2003).

Table 8.2: Sample of Participants for Usability Testing

Age Category	Number of Participants	Gender
20-29	2	Male & Female
30-39	2	Male & Female
40-49	1	Male
50-59	1	Female
60+	1	Male

Table 8.2 shows that seven participants from five age categories were chosen to complete the user testing. In total, four males and three females were included in the testing. All the participants had been subscribers to the popular digital TV broadcasting service for over six months, with the inherent understanding of the current workings of the PRC and how they typically used the PRC to perform certain tasks. This knowledge was vital to the usability testing

process as participants were able to comment on whether the VRC, based on the proposed set of user interface design guidelines, was usable or not and whether it enhanced their UX.

8.3.2 Procedure

The designs for the VRC prototype were guided by the proposed user interface design guidelines (Chapter 7) created from the review of literature (Chapter 3 and Chapter 4), and data collected from the CTA (Chapter 5), as well as brainstorming focus groups (Chapter 6). These user interface design guidelines were used to test different UI functionality on the VRC prototype.

The reason the researcher decided to test users within their own home environments, and facilitated the user testing sessions, was in order to eliminate the confusion and issues found while conducting remote tests. Remote testing makes it difficult to resolve issues that occur when running the test prototype, since the testing is performed remotely and users' motivations regarding exploration of the prototype might be interpreted as confusion. Other difficulties that arise with remote testing are that users could misinterpret the tasks and questions asked, which would alter the results.

The VRC prototype was not fully functional, therefore certain features were simulated in order for the user to understand how the VRC would work. For example, when users pressed a channel on the VRC they were told that the channel on the TV had changed to that particular channel. A think aloud method was used during the testing which encouraged participants to talk out loud and explain what they were doing as they were performing the tasks. Participants were asked to say what they were thinking, looking at, and doing at each stage during the tasks. This method was helpful in determining users' expectations and identifying what aspects of the system were confusing.

A pilot test of the scenarios was completed prior to the usability testing, in order: to determine if there was adequate time for the session, to resolve any logistical problems with the test setup, and to ensure the prototype was able to handle the user interface functionality. Participants for the usability testing were greeted, and they signed the consent forms. Once the participants were settled, the voice and video recorders were activated, and the participants were given the scenario instructions and were told to think aloud during the entire usability testing session. The sessions lasted for a maximum of one hour. Participants were initially asked about their first impressions of the VRC prototype. Participants were then asked to complete all the scenarios,

followed by a post-task evaluation questionnaire using a system usability scale (SUS) (Brooke, 1996).

Task Success

Task completion was used to determine the usability of the VRC, as described in Kuniavsky (2003). Time and error rates were not used as the usability metrics since this was the first time the users had ever operated the VRC prototype, and there was a potential learning curve to overcome, which could have affected the amount of time taken to complete tasks, and the number of errors made (Jokela *et al*., 2006). The results were also not being compared with any other prototypes therefore time was not kept for completion of tasks.

Scenarios were used to give participants context within which they needed to complete tasks. The scenarios were used to test the various features within the functional categories through the use of tasks. Each functional category comprised features, for example, the functional category 'all channels' comprised features such as channel icons, audio, and programme information. Task success was measured on whether users could complete a task on their own, if they completed a task with assistance, or if they did not complete the task. The completion of a task with assistance occurred when users asked the researcher for help. For example, users were unsure of which gestures to use and asked the researcher to assist them.

Five main functional categories of the VRC were chosen to be tested within the one hour period, in order to allow enough time for task completion and to discuss users' feedback, as suggested by Kuniavsky (2003). The five functional categories: all channels, TV guide, favourites, PVR menu, and settings, were based on some of the most common tasks that were discovered during the CTA (Section 5.4.2 and Section 5.6), as well as some tasks that users had difficulty with. Within the five functional categories, twelve features were tested in the context of each functional category. The tasks were designed to be reasonable, doable, and detailed to allow participants to complete them in a reasonable amount of time. The task success results were analysed by using frequency counts.

The following section describes the functional categories that were focused on during the usability testing, as well as the scenarios for each functional category, and the tasks which the participants were asked to complete. The first functional category, changing channels, is specifically related to section 5.4.2.1, section 5.4.2.2, and section 5.4.2.9, from the CTA. The second functional category, TV planning, relates to section 5.4.2.3 and section 5.4.2.4 of the

CTA. The third functional category, favourites, refers to section 5.4.2.5 of the CTA. The fourth functional category, PVR menu, is related to section 5.4.2.6, section 5.4.2.7, section 5.4.2.10, and section 5.4.2.12. The fifth functional category, settings, correlates with section 5.4.2.11 of the CTA.

Functional Category 1: Changing Channels

Scenario 1: You arrive home from town and decide to browse the TV channels to see what is showing:

Task 1: you first change to channel 105 to determine what programme is currently showing

Task 2: then you change to "Storage Wars" on channel 123 and want to find out more about this programme

Task 3: finally you want to change to Channel 101 as quickly as possible

Functional Category 2: TV Planning

Scenario 2: You have had a busy day at work and want to unwind before your friends come over for dinner. You decide to organise your TV viewing for the evening so that you do not miss any good shows before your friends arrive:

Task 4: you would like to see what programme is showing 'Today' at 18:00 on channel 107 and you take note of the episode number

Task 5: you create an 'auto-tune' for the programme you have just found (Task 4)

Functional Category 3: Favourites

Scenario 3: Since you have been busy at work, you have realised that you have less time on your hands to relax and do not want to scroll through all channels, just certain ones:

Task 6: you decide that you enjoy channel 101 so much that you want to make it one of your favourites

Task 7: then select channel 101 from favourites

Functional Category 4: PVR Menu

Scenario 4: You missed one of your favourite programmes when your friends came over for dinner and decide to watch the programme now:

Task 8: you play a series called “Necessary Roughness” on catch-up
Task 9: you adjust the volume for the programme “Necessary Roughness”
Task 10: you then mute the volume because you hear a strange noise outside
Task 11: you delete the programme once you have finished watching it

Functional Category 5: Settings
Scenario 5: You are looking after your friend’s children and the movie you have selected to watch has a lot of foul language in it:

Task 12: you decide to change the language settings to English-Family

Participants were probed about their thoughts and experiences regarding certain features on the VRC, and were given time to ask questions if they were unsure about anything (Kuniavsky, 2003). Once the participants had completed all the scenarios, they were asked if they had any final remarks regarding the VRC prototype, and were then asked to complete the SUS questionnaire.

Post-test Questionnaire

Pirker *et al*. (2010) investigated the possible entry barriers to usability and user experience of touch interaction in a living room environment. They utilised the SUS to collect users’ overall impressions of the VRC prototype (Brooke, 1996). SUS has been used to test a variety of devices and is independent of the technology it is tested on, for example, consumer software, mobile phones, hardware, and websites (Sauro, 2011). The SUS enables the researcher to measure ease-of-use (usability), learnability, and overall user satisfaction (Brooke, 1996). SUS produces reliable results from the repeatability of the responses of users, and the validity of SUS is effectively presented through the variety of questions related to system usability, such as the need for training, support, and complexity (Sauro, 2011). Similarly, this research used a SUS to measure users’ subjective perceptions of the usability of the system (Sauro, 2011). The SUS was handed to the participants once the usability test was completed. A frequency count was used to measure how many participants selected the various options on the five point Likert scale. The Likert scales ranged between strongly disagree and strongly agree (Sauro, 2011).

The scoring for the SUS was as follows (Brooke, 1996):

- Odd numbered questions: subtract one from the user response.

- Even numbered questions: subtract the user response from five.
- This balanced all values from 0 to 4 (four was the most positive response).
- All converted responses for each user were added up and the total was multiplied by 2.5.
- This converted the range of possible values from 0 to 100 rather than 0 to 40.

8.4 Results

8.4.1 Task Success

Participants were asked to complete five scenarios that contained a total of twelve tasks, which included the following functional categories: changing channels, TV planning, favourites, PVR menu, and settings. The results for functional category 1, changing channels, show that all the participants completed Task 1 by themselves. The tasks that were completed successfully were possibly due to the flow of the screens being clear enough to show users where they could find the information they were looking for, in order to complete the tasks. The users particularly mentioned the simple navigation between the screens. One participant was able to complete Task 2, while six participants did not complete the task (Figure 8.1: Results of Changing Channels Tasks). The reason that some tasks were incomplete was due to users demonstrating their learning of the VRC prototype during the testing, and with a few tweaks to the user interface the users may have been able to complete the tasks. The main reason for not completing the task was that participants were unaware of which gestures to use in order to gain more information about the programme. Participants had to learn which gestures to use to gather more information and this could be resolved using a tooltip. Task 3 was completed with assistance. Participants performing Task 3 (Figure 8.1: Results of Changing Channels Tasks) found it tricky and required assistance, since they were not familiar with the ‘last viewed’ functionality. This representation of alternating between channels had never been experienced by users, since the users, would normally select the ‘Alt’ button to alternate between channels. Participants did notice the ‘last viewed’ bar but reverted back to their original method of scrolling through the screens to change the channel. The use of the ‘last viewed’ bar would increase, as participants used the system more, and learnt the shortcuts for changing channels.

The figures below show the frequency of the tasks that participants had completed, completed the tasks with assistance, or had not completed the tasks.

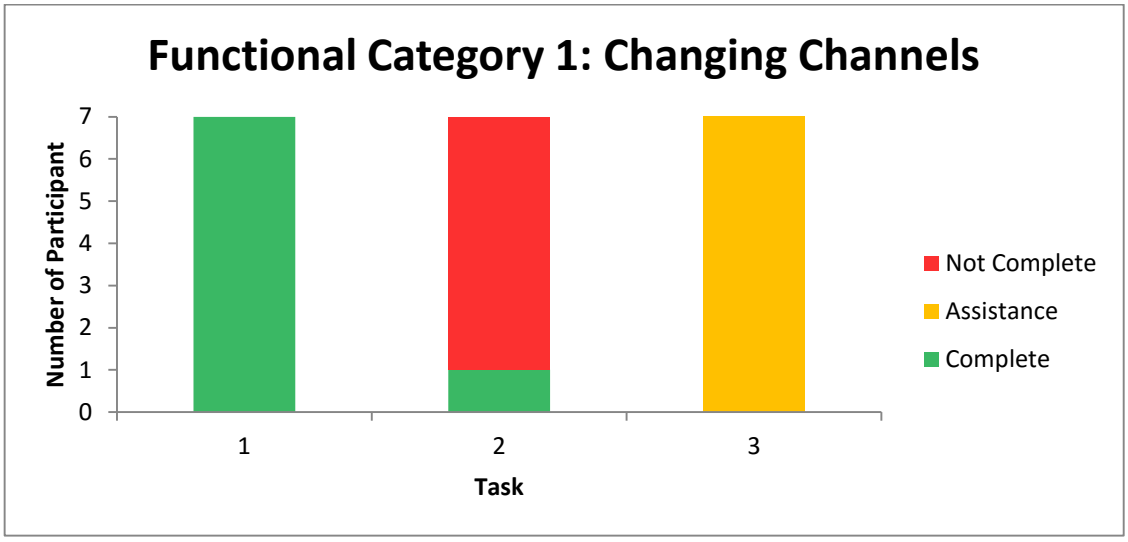


Figure 8.1: Results of Changing Channels Tasks

Four out of the seven participants completed Task 4, however, three participants required assistance (Figure 8.3). Participants asked if they were able to scroll the screen, and the researcher assisted them and told the participants that they could scroll the screen.

It was unclear to users that they could scroll down the screen, since the visual cues (scrollbars) were lacking, therefore, users could not find the information they were looking for without the assistance. The users were familiar with gestures (scrolling) but were unaware that they needed to scroll in order to find more information. Other users did not understand what the 'E' signified on the TV guide page. When users asked the researcher what it meant, the answer assisted them to give the correct episode number. Similarly, users needed assistance with Task 5 since they asked if the 'A' would auto-tune the programme (Figure 8.2). Task 5 was completed by three participants out of the seven. Another three participants needed assistance to complete this task, and one participant was unable to complete the task. The one participant did not complete the task since they did not know what the 'A' symbol meant. The user was unfamiliar with the terminology and 'A' did not mean anything to them. Using a label with the words auto-tune would be more descriptive to users.

Figure 8.2: Episode and Auto-tune

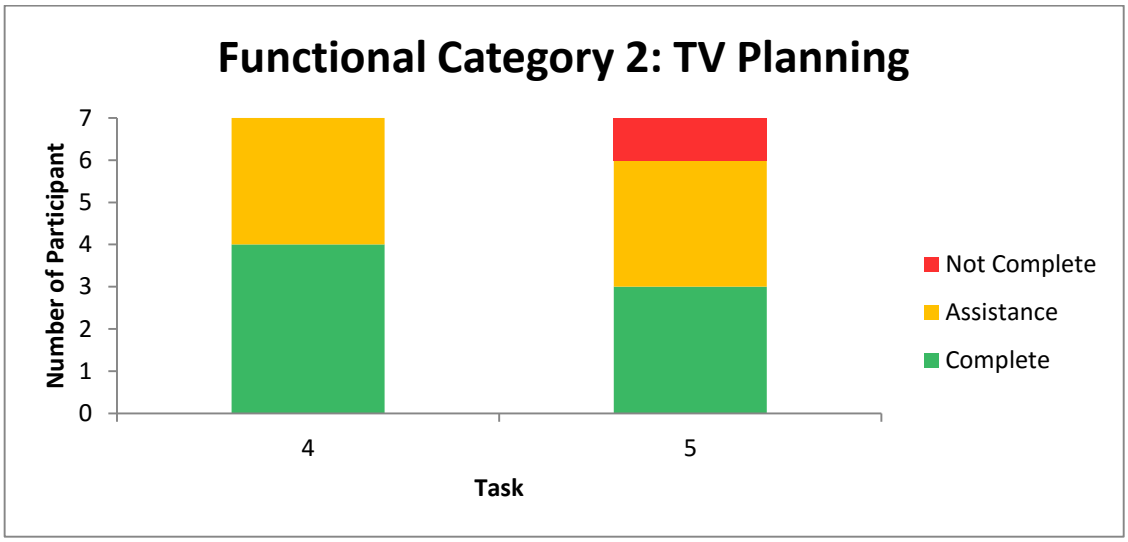


Figure 8.3: Results of TV Planning Tasks

Five participants were unable to complete Task 6 (Figure 8.4). The main reason for not completing the task was that users were unaware of what the star represented. Their mental models for a star symbol did not correlate with adding favourite channels. A label could be included underneath the star (space permitting), and a 'favourites' button should be inserted for users to add favourite channels on the favourites screen. Alternatively, a tooltip should be used. One participant was confused in Task 7, and needed assistance with trying to find their favourite channels. The one participant was unsure of where to find the favourite channels, since the participant was unfamiliar with the system and was assisted by the researcher. The participant found the favourite channels and said they would remember this process for next time. There was a short learning curve for using the VRC system. Once users became aware of where to find the information they needed, they remembered how to get there.

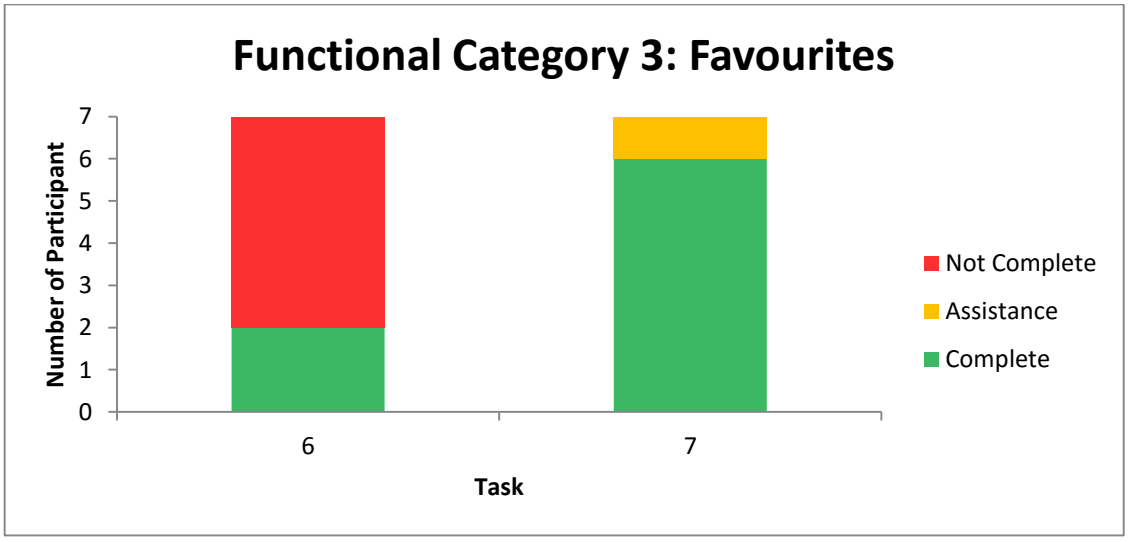


Figure 8.4: Results of Favourites Tasks

The results show that all participants completed Task 8, Task 9, and Task 10 without assistance. Four out of seven participants were able to complete Task 11, yet three participants required assistance (Figure 8.5). The participants needed assistance since they thought the 'x' next to the list of programmes was to close the programmes and not to delete them. The researcher assisted the participants when they asked if the 'x' would delete or close the programme. The participants' mental models throughout the VRC system associated 'x' with a close feature and not delete. The consistency of using 'x' in the same way throughout the prototype needed improvement, and the inclusion of a separate delete option was required.

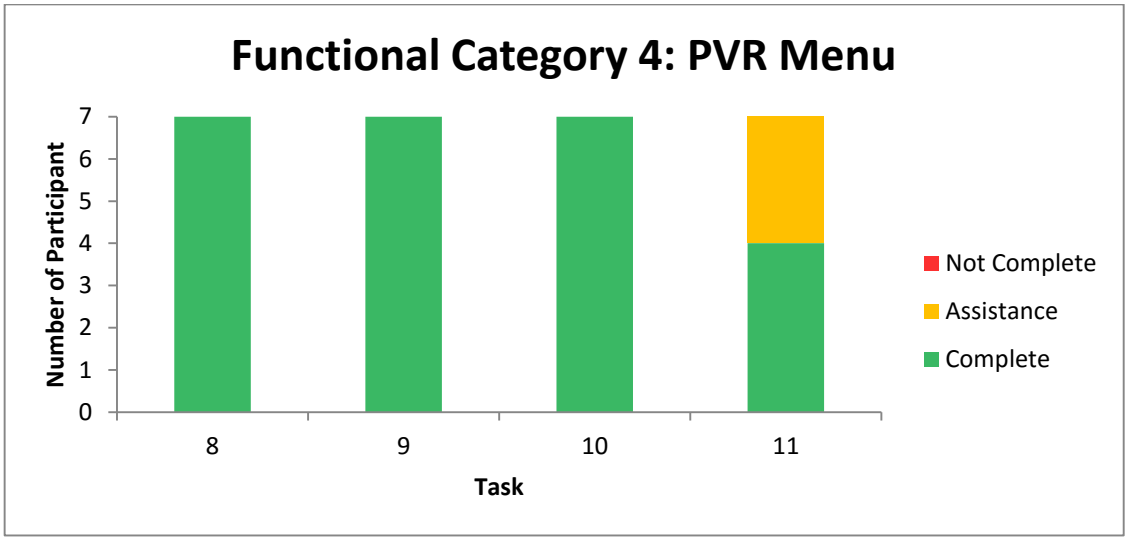


Figure 8.5: Results of PVR Menu Tasks

All participants completed Task 12 without assistance, implying that the settings screens were easy to use and understand (Figure 8.6).

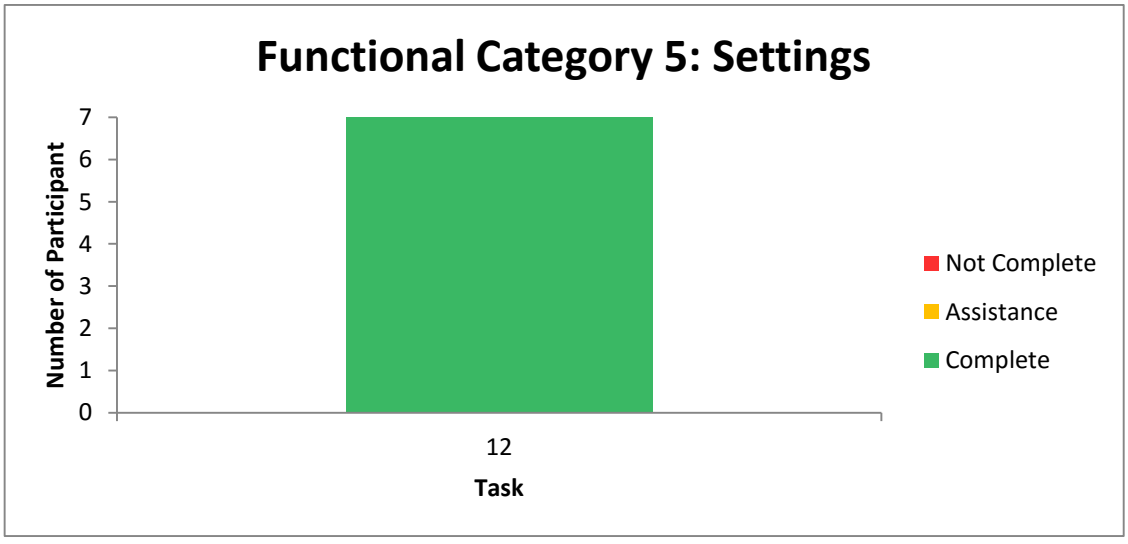


Figure 8.6: Results of Settings Tasks

8.4.2 User Feedback

8.4.2.1 User Impressions

The user impressions were gathered during the usability testing and summarised in APPENDIX B. The information shows the overall comments from all the participants and includes their first impressions, final remarks, and any interesting quotes from the testing sessions. APPENDIX C indicates the detailed usability issue list for all the participants, which focused on the issues participants had when completing scenarios, as well as the issues they had with features that were not specifically tested. The design guidelines were used to categorise the issues found during the user testing. The names of the tasks, area where the task took place, and the issues participants identified when completing the tasks, were also listed. The issues identified by participants were listed, and suggestions were made by participants to overcome the usability issues. Both the user impressions (APPENDIX B), and detailed usability issues (APPENDIX C), are described further below.

Five participants commented on the homepage (Section 7.4.1 Figure 7.2), saying that it was well set-out, clear, simple, not too complicated, and informative. These comments imply that the simple layout of the homepage was effective, uncomplicated, and allowed participants to easily find what they were looking for. The overall impressions from all the participants were that the buttons were a good size, easily accessible, and users could press the buttons effortlessly without having to aim. The participants also liked that there were a minimal number of buttons (only five on the homepage) on the VRC, compared to PRCs (twenty or more buttons). Two participants enjoyed the relative uniformity of the design and number of channel buttons on the screen (Section 7.4.2, Figure 7.3-A). One participant mentioned that they did not want the UI to become overcomplicated, "*the simpler the better*". Another participant echoed this comment, saying the VRC was simple and uncomplicated. One participant felt more inclined to explore the features on the VRC than on a PRC, since the VRC seemed more user friendly to a novice user. The results indicate that a simple UI, which does not detract from the tasks users want to perform, and well-defined information architecture may help to improve the usability of the VRC and user satisfaction of using the VRC. One user did not like that there was an uneven number of buttons on the homepage. To make the design symmetrical, a graphic can be placed in the empty space to create a more uniform look. Alternatively, the favourite channel functionality could be placed within the all channels button, and the favourite channels button removed from the main screen. Another user said the buttons on the homepage (Section 7.4.1 Figure 7.2) did not have impact. Changes in the colour and dimension of the buttons may help to improve the overall look and feel of the buttons, and create a more impactful look. One user in particular said that there was

no need to have the power button available all the time. The power button could be placed on the homepage and nowhere else, so to avoid accidently turning the VRC off when operating other features on the screen.

The button labels were a legible size and self-explanatory, enabling users to understand what they would find under each label. The button style and colour was plain and did not need decorations, "*the simpler the better*". One participant commented that they liked the text size. They thought the font was clean and simple, and the font colour (white text on a black background) was good (Section 7.4.2, Figure 7.3-A). The results show that the labels should use a well-defined font, with neutral colours, that are large enough to be legible to most users, and comprehensive text that encompasses what the items represent. Five of the seven users were unsure of what the letters S, E, A, and B signified (Section 7.4.7 Figure 7.5-B). One user in particular said they thought the A and B were synchronicity items that allowed users to switch between modes, and did not think that they were to auto-tune and banner (reminders for) a programme. The users' mental models varied with regards to the meaning of the letters, therefore, the full words should be written out for each item to clarify to the users what the letters mean. For example, season (S), episode (E), auto-tune (A), and banner (B). One user did not know the universal sign for power on/off, and five other users did not know what the star icon represented (Section 7.4.8 Figure 7.6-A). This result suggests that all symbols should have written words (labels) near them to explain to users what the various symbols denote, since all users' mental models differ. Another user was uncertain of where the home button took the user. A title/label placed in a prominent position on the homepage, will give users a reference point of where they are, and once they select the home button they will know where the button takes them.

All seven participants considered the last viewed bar (Section 7.4.2, Figure 7.3-A) to be extremely useful and "*very cool if it was scrollable*", as well as "*nice and very handy*". The last viewed bar was useful in terms of speed, easier to switch between channels, and was a great feature on the VRC. These positive results showed that the 'last viewed' shortcut bar helped users to quickly switch between channels, reducing the time spent scrolling through the channel options, which may improve the usefulness of the VRC.

Two participants mentioned the number pad (Section 7.4.5 Figure 7.4). One participant, in particular, liked the placement of the number pad and said that it was highly visible. Two users noticed that there was no backspace button on the number pad. A backspace button placed on the

number pad would allow users to correct any mistakes made when entering channel numbers. It was noticed by some users that there was no back button on the touchscreen, however, the smartphone itself had a back button that functioned in the same way. A back button could be placed on the screen, however, if a user was familiar with the device they would know where to find the button. A tooltip can be utilised to make users aware that there is a back button on the device if need be. Another participant said that they would find it difficult to type in numbers of channels into the number pad quickly, since they could not feel the buttons. The users' feedback showed that the number pad was in a noticeable position, however, users were concerned about the lack of tactile feedback when pressing buttons. The VRC prototype version was unable to include tactile feedback, however, future versions of the VRC should make use of the phones' physical vibrate feedback mechanisms for tactile feedback.

Participants enjoyed scrolling through the screens and found it far quicker and natural to find correct information than using buttons (Section 7.4.2, Figure 7.3-A). Participants said that once they knew to do certain gestures to access information, they would remember which gestures to use throughout the VRC. Some users were unsure if they needed to scroll up/down or left/right on the all channels screen as well as the TV guide screen (Section 7.4.6 Figure 7.5-A). A visual indicator such as a scroll bar can be used to lessen the confusion felt by users and to show them the way to scroll to get more information. Using gestures consistently throughout the VRC may help to improve users' learnability of the application, and will hopefully improve their efficiency when using the VRC. One user became very frustrated when the prototype scrolling feature was not working correctly (due to the responsiveness issues of the prototype). These results presuppose that there was a short learning curve involved with using gestures to navigate through the VRC. The results also showed that immediate feedback and quick responses are vital elements that may improve the user experience and usability of the VRC. The researcher included scroll bars for the volume and the multimedia functions (Section 7.4.11 Figure 7.7-B), however, the scroll bars for the page were omitted and should be included in future VRC designs. Users were unaware that they needed to press and hold the channel icon on the 'all channels' screen to get more information about the programmes being displayed on that channel. Behaviour and gestures can be taught to users by using a tooltip (with the option to never be shown again) to show users how they can access information on all the features.

The multimedia buttons were noticed to be too small on the PVR screen (Section 7.4.11 Figure 7.7-B). The size of the multimedia buttons should be increased and the colour green utilised to emphasise the play button. Using different colours may help to bring more visual attention

towards the multimedia player. Four users commented that the multimedia player buttons and scroll bar were too close to each other, implying the space between the two features should be increased in order to reduce possible errors that could be made.

One participant preferred the layout of the TV guide on the VRC (Section 7.4.6 Figure 7.5-A) to the one on the TV screen saying, "*the VRC TV guide is simpler and more effective*". Similarly, another participant enjoyed the layout of the TV guide on the VRC, saying that it was easy to read and scroll through. The comments imply that information needs to be laid out in a simple manner that is legible and easily accessible to users. The mobile phone and the touchscreen capabilities allowed for easy scrolling and increased legibility of the text, since the screen was closer to the user. This allowed users to read the text more easily on the VRC than on the TV at a distance. Users noticed the limited number of programmes displayed for each day in the TV guide (Section 7.4.7 Figure 7.5-B), saying *"there are not enough programmes displayed for each day."* A reasonable balance needs to be maintained between the amount of content on the screen and the size of the text. The text needs to be legible and well-spaced out to allow for easy reading. One user commented on the closeness of the text in the PVR menu. This alludes to the previous 'recommendation' that text should be well-spaced to allow for better reading.

The overall comments regarding the settings (Section 7.4.13 Figure 7.8-A) were that the layout was clear, self-explanatory, straightforward, and easy to understand. The settings were "*spelt out for you*" in a list format, and the process of changing a setting was very simple. These results imply that a simplified process with straightforward wording may help users to select the correct options and change their settings with ease, in an attempt to improve the usability and efficiency of the VRC. A user commented that they were unsure what 'information' would entail within the settings list. The 'information' included details about technical specifications for the VRC, therefore, the word technical can be placed in front of the word 'information' to be more descriptive for users.

Two participants raised concerns about whether more than one VRC could be operated in a household, and whether the mobile phone would be moved around the room to allow visitors to change the channels. The technical aspects of the VRC fall outside the scope of this research, however, these concerns should be addressed in future research.

Two participants commented on the positioning and colour of the volume bar (Section 7.4.2, Figure 7.3-A), saying it was good and that the slider (volume bar) was appropriate for a

touchscreen phone. The results indicate that using gestures on a touchscreen phone was the most appropriate way to interact with particular elements on the screen (volume bar), and may help to improve the usability and efficiency of users performing various tasks. Users thought the help button was specifically related to the volume bar due to its position. This indicates that the space between the help button and volume bar is too close, and users assume that the two features are related due to their closeness and proximity. The space between the help button and volume bar can be increased in order, to attempt, to eliminate this confusion. Alternatively the help button could be labelled 'help'.

One participant liked that they could see what was going to show on another channel without changing the channel (Section 7.4.3, Figure 7.3-B), and that many TV programmes were displayed in specific channels on the TV guide. Two participants said it was useful to get extra information about the programme they were watching by accessing the internet link on the page, and would use the website link to check the ratings of movies and age restrictions (Section 7.4.4, Figure 7.3-C). Users were unsure of what the website link was for, since they were unfamiliar with the website name. Placing a label next to the website name may lessen the confusion for users, and reveal what the link is for. Allowing users to type in a website address would enable them to have more freedom when looking for movie reviews on other websites.

Most of the participants liked that all the actions (tasks) happened on the mobile phone itself, that it was simple to use, and that the VRC was a lot closer and therefore it was easier to see smaller details. They commented that the VRC was accessible, portable, and easy to access. These results indicate that using a mobile phone to display all the content improves the readability for the users, as the information is closer to the user. The portability of the mobile phone may help to enhance the user satisfaction and experience for the participants. One participant, in particular, enjoyed having the ability to switch between the TV guide, news, and weather options (Section 7.4.2, Figure 7.3-A). The results imply that users enjoyed having 'second screen' capabilities, a touchscreen smartphone, and TV screen. The results also imply that the users enjoyed the uninterrupted viewing of their TV programme, as well as the accessibility to additional information (website link and TV guide) regarding the TV programme the users were watching. The icons looked modern, however, the tabs looked too simple and one participant said the VRC needed to have better aesthetics (Section 7.4.2, Figure 7.3-A). The results indicate that the aesthetics need to be improved in order to enhance the overall appeal of the VRC, to improve the user satisfaction.

Three participants enjoyed the thematic groupings of the channels (icons). One participant, in particular, said it is "*great to have all the channels under different headings to make the selection easier*". The results indicate that the use of good labelling may increase the rate at which users find content, and might allow users to use the VRC more efficiently. The headings for the channel categories and weekday labels in the TV guide (Section 7.4.2, Figure 7.3-A and Section 7.4.7, Figure 7.5-B) were not noticeable, or large enough for all users. Increasing the size of the font, making the labels bold, and centralising the headings may help to make the categories more noticeable and legible.

Two participants said they would use the search feature (Section 7.4.6, Figure 7.5-A) to find specific programmes, and to sift through more data. One participant said "*it is vital to have a good search feature*". The results indicate that allowing users to have a comprehensive search feature enables them to find content more easily, and may improve the user satisfaction with regards to accessibility to information.

Users were unaware of how to add a favourite channel (Section 7.4.6, Figure 7.5-A). The VRC did not correlate with the users' mental models of how they would add a favourite channel. The star was not an obvious symbol to bookmark a favourite channel, and six of the users expected to see an 'add favourites' button within the favourite channels feature. A favourites label could also be added next to the star icon. In another instance, all seven users expected the recorded programme to begin playing immediately when pressing the play button on the list of PVR programmes (Section 7.4.10 Figure 7.7-A). The icon on the list of PVR programmes was misleading to users, therefore, removing the icon from the list would lessen the confusion felt by users.

One user was unsure of how to delete a favourite channel once it had been added to a list (Section 7.4.9, Figure 7.6-B) and, similarly, five users were unsure of how to delete a programme within the PVR feature. Users did not expect the 'x', which was placed on the PVR list, to delete PVR items. Users thought the 'x' represented 'close' since that is how it was used throughout the VRC (Section 7.4.11, Figure 7.7-B). A consistent process should be used to delete a programme or channel. For example, users can press and hold the programme or channel down, waiting for a popup to appear with options to delete the item. The alternative is to include a delete button on the screen to allow users to easily delete an item. The delete button should be located in a 'hard to reach' place to prevent users from accidently pressing it.

Six users commented that the information pop-up box showing the programme information for the channel disappeared too quickly (Section 7.4.3, Figure 7.3-B). Users needed more time to read the synopsis for the programme and should be given the choice to close the pop-up themselves, and in their own time. This gives users more control over the VRC environment. All seven users commented that it was not clear if a programme was being auto-tuned (Section 7.4.7, Figure 7.5-B) since there were no visual indicators. Similarly, the same was true when users added a favourite and were unsure if the channel had been added. Visual feedback needs to be given to users to show them the programme is being auto-tuned, or added to favourites. An 'A' could be displayed next to the item being auto-tuned (similarly for banner and record features), or a confirmation message could be displayed to users confirming the programme will be auto-tuned, or that a favourite channel has been created. Four users said they were unaware if the language changes had been accepted by the VRC (Section 7.4.13 Figure 7.8-B). The selected language did change colour to blue however users wanted more feedback from the system. A visual indicator is needed, for example, a tick next to the language that has been selected or a popup box confirming the changes.

8.4.3 Post-task Questionnaire

Overall there was a positive response from the users regarding the ease of use, learnability, and user satisfaction of the VRC. The System Usability Scale (SUS) was used to collect data about whether participants found the VRC prototype to be usable or not, and what their overall satisfaction level was with the VRC. Table 8.3 and Figure 8.7 show the frequency count of the SUS questionnaire, indicating which users found the VRC prototype to be usable (ease of use), learnable, as well as their levels of satisfaction with the VRC, based on a scale between strongly disagree and strongly agree.

Table 8.3: System Usability Scale Questionnaire Frequency Count

Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
			Frequency Count Chart		
1. I think that I would like to use this system frequently	0	0	0	1	6
2. I found the system unnecessarily complex	4	3	0	0	0
3. I thought the system was easy to use	0	0	0	4	3
4. I think that I would need the support of a technical person to be able to	6	1	0	0	0

	use this system					
5.	**I found the various features in this system were well integrated**	0	0	0	6	1
6.	**I thought there was too much inconsistency in this system**	2	3	1	1	0
7.	**I would imagine that most people would learn to use this system very quickly**	0	0	1	3	3
8.	**I found the system very cumbersome to use**	5	2	0	0	0
9.	**I felt very confident using the system**	0	0	3	2	2
10.	**I needed to learn a lot of things before I could get going with this system**	3	2	0	2	0

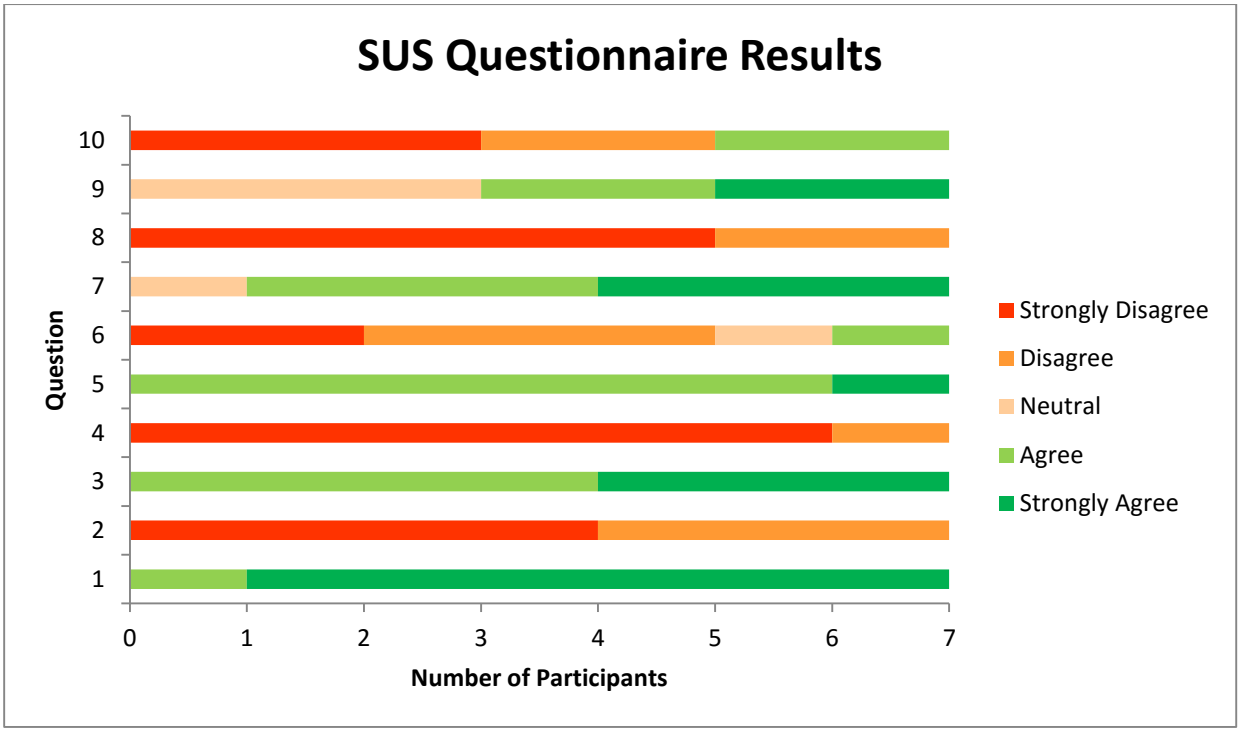


Figure 8.7: SUS Questionnaire Results

8.4.3.1 Ease of Use

Questions 2, 3, 5, 8, and 9 all referred to the ease of use of the VRC prototype (Table 8.3). The results from question 2, 3, and 8 revealed that the VRC was usable, uncomplicated, and straightforward to use. Question 5 indicated that users found the various functions to be well integrated, suggesting that the flow of the VRC was good, and that all necessary functionality was appropriately included into the VRC prototype. More than half of the sample felt very confident using the prototype (Question 9). This could be due to users operating and viewing the

VRC for the first time. The learning curve for the system was short, since users did mention that once they knew how to use the gestures or features, they would remember the actions involved when completing certain tasks.

8.4.3.2 Learnability

Questions 4, 7, and 10 aimed to gain an understanding of how easy the system was to learn (Table 8.3). The results from questions 4, 7, and 10 revealed that all levels of users (novice, average, or expert) should be able to 'figure out' and learn how to operate the system on their own, and relatively quickly. The hesitance from the one user (Question 7) could be attributed to first time use of the VRC, or not knowing how to use gestures on a touchscreen phone. Two participants agreed that they did need to learn a lot of things before they could get going with the system (Question 10). The users had never seen the VRC prototype before and needed to learn which gestures to use to perform certain tasks, such as gaining more information about a programme on a particular channel, or which way they needed to scroll through the screens (up and down, or left to right). Visual indicators such as scroll bars and tooltips may help users to become accustomed with the VRC in a shortened period of time.

8.4.3.3 User Satisfaction

Questions 1 and 6 were associated to the overall user contentment with the system, and users' positive or negative reactions towards the system (Table 8.3). The results indicated that users would operate the system frequently and found the VRC system useful. The majority of the users thought that the VRC was consistent. One participant was neutral about whether the VRC was too inconsistent, and another participant agreed that the VRC had too much inconsistency. A possible reason for users thinking the VRC was inconsistent, could be due to the 'x' labels being used for close and delete, thus using the 'x' functionality metaphor inconsistently.

Table 8.4 indicates the questions for the SUS, and the SUS scores users achieved, as well as the calculations of their total scores. Bangor *et al.* (2008) suggested that products which are at least acceptable have SUS scores above 70, with better products scoring in the high 70's to upper 80's. The higher the users' scores, the higher the overall usability satisfaction with the VRC. The overall SUS score totals show that the mean is 82.5, and the median for all participants is 82.5. The SUS scale reflects that the VRC prototype is considered to be very usable.

Table 8.4: Ordinal data collected during SUS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
1	4	3	3	4	3	3	3	3	2	3	77.5
2	4	3	4	4	3	3	4	3	4	1	82.5
3	4	4	3	4	4	2	3	4	2	1	77.5
4	4	3	3	3	3	4	4	4	2	3	82.5
5	3	4	4	4	3	1	3	4	3	1	75
6	4	4	4	4	3	3	4	4	4	4	95
7	4	4	3	4	3	4	2	4	3	4	87.5
Mean											82.5
Median											82.5

8.5 Discussion

The usability testing was used to test the proposed user interface design guidelines and functional interface guidelines, through the VRC prototype instantiation, suggested in Chapter 7; and to understand users' acceptance and satisfaction of the guidelines, as well as the impact they had on users. The usability testing gathered information about participants' user experiences involving the VRC prototype, and allowed the researcher to explore the issues participants discovered when performing VRC tasks, in order to better inform the set of VRC user interface design guidelines.

Overall, users said the look and feel of the VRC was informative, simple, uncomplicated, and user friendly for novices. This confirms guideline 9 and reiterates what Lee *et al*. (2008) and Pirker *et al*. (2010) suggested, stating that UI display styles need to be well designed and maintain a balance between the level of simplicity and functionality. Morville (2004) and Maassen (2008) both agreed that a great look and feel is vital for a good user experience. This result reaffirms the findings from the CTA that indicated PRCs display all buttons permanently, whereas, VRCs are able to display buttons on different screens; making the screens look simple, less cluttered, and uncomplicated, as suggested in guideline 5 (Table 7.4), guideline 7 (Table 7.6), and guideline 9 (Table 7.7). Similarly, the SUS results showed that participants agreed that overall, the system (VRC) was not complex and it was easy to use. This finding was reiterated during task 12, where all participants thought that changing the settings was simple and easy. These findings validated guideline 9 (Table 7.7), and guideline 14 (Table 7.10), pertaining to simple, intuitive, uncluttered layouts, with simple, uncomplicated settings functionality. The post-test questionnaire results (Table 8.3) showed that even though users have never used the VRC and were unfamiliar with its usage, all users ultimately said they would like to use the

system frequently. This result shows that it has overcome some of the issues related to PRCs in section 4.2.1, and section 4.2.6.

Task 3 showed that the participants needed assistance since they were unfamiliar with the system. However, once the users were told that they could press the last viewed bar, they said they would definitely use this option to quickly change between channels. This point is echoed by Tognazzini's (2007) principles regarding learnability of new systems. The participants found the shortcut (last viewed bar) to be extremely useful to quickly switch between channels, to allow for efficiency of use which confirms guideline 14 (Table 7.10), and reiterates what Nielsen (1993) said regarding usability. Similar to the PRC (section 4.2.2), the VRC used a 'button shortcut' that allowed users to quickly select features without pressing too many buttons. The use of interactive technologies (VRC) helps to limit the number of buttons per screen and allows broad access to a range of features (Wang *et al*., 2009). This finding reiterates guideline 5 (Table 7.4) regarding shortcut functionality, and guideline 16, which confirms the functionality users wanted VRCs to have.

Participants thought that the size and colour of the buttons, icons, and labels were suitable for the VRC and screen size. Huang and Lai (2008) showed that the size of icons affects the usability of touchscreen devices, therefore, the button sizes were made to be between 7mm and 10mm to allow for the best performance from users, which the participants in the study responded well to. The VRC button sizes were intentionally increased to be larger than the PRC buttons sizes, since the review of literature and the CTA found the PRC button sizes were at times, too small (section 4.2.3). This finding also validates the guidelines regarding button sizes in guideline 7 (Table 7.6) and colours used in guideline 10 (Table 7.7).

Participants also commented that the names (labels) of the buttons were clear and self-explanatory. The clear, informative labels helped users with their logical navigation through the VRC since features were well-grouped. This finding confirms guideline 15 (Table 7.10). Nielsen (2004) suggested that unclear button label choices decrease the usability of remote controls. Guideline 3 (Table 7.3) suggested the use of familiar terminologies in order to overcome ambiguous labels that were used in the PRCs (section 4.2.5). The text sizes used were large enough for the users to read on the VRC, which confirms guideline 10 (Table 7.7).

Participants liked that there were fewer buttons on the VRC (Section 7.4.2, Figure 7.3-A) than the PRC (section 4.2.1), as one participant indicated that often "*90% of the ones* (buttons) *on the*

PRC were never used". Cooper (2008) suggested that a vast number of button choices created confusion and frustration for users when using remote controls. This validates guideline 7 (Table 7.6) regarding decreasing the number of buttons per screen.

Participants preferred the layout of the VRC TV guide to the current TV guide, accessed via the PRC, and found it easy to read and scroll through, which confirms guideline 12 (Table 7.9) regarding natural methods for interaction. Screen layout is a vital part of a user's navigation through a system (VRC). The input fields used, titles describing menu options, and the style of the UI used, may affect the usability of the UI and the ultimate satisfaction of the user (Norman, 1988; Heo *et al*., 2009). The layout of the settings were clear, straightforward, and were easy to change (guideline 14); which attempted to improve upon the design of the PRC settings, since users that had changed the settings, using their PRC, had confused themselves by the process. This validates guideline 5 (Table 7.4) regarding easy navigation, and guideline 9 (Table 7.7) that referred to simple screen layout.

Participants liked that the actions were performed on the mobile phone itself, making tasks easier to complete. Participants liked that the mobile phone was more accessible, portable, and that the features were a lot closer to the individual, via the 'second-screen'. The satisfaction of the dual/second screen capabilities, allowing users to change the channels on the VRC without interfering with what is being viewed on the TV, echoed the trend in second-screen interaction in home technology (Cooper, 2008; Simon *et al*., 2013). This finding echoes the functional interface guideline 13 (Table 7.10).

Participants enjoyed scrolling through the VRC screens, and thought this was a quick and natural form of interaction. This confirms guideline 1 (Table 7.1) regarding immediate feedback, and guideline 12 regarding natural interaction (Table 7.9). The post-test questionnaire showed that participants thought they would not require technical assistance to use the system. Not all the gestures were apparent to the participants. Users were unaware as to whether they needed to scroll up/down or left/right, therefore a visual scroll indicator was needed to show users the correct way in which to scroll, as suggested by guideline 9 (Chae & Kim, 2004; Nilsson, 2009; Nielsen, 2011). Tooltips were suggested to solve problems and inform users that they needed to press and hold the channel icon down in order to get more information about the programmes being shown on TV, without changing the channel. Nielsen (1993) suggested help and documentation for users that needed assistance. Participants said that once they learnt which gestures to use, they would never forget them (quick learning curve). Tognazzini (2007) said that

it was imperative to balance the importance of usability with learnability, to enable users to easily learn how to use a system efficiently. Guideline 14 (Table 7.10) suggested context sensitive help which could be implemented in future VRCs as tooltips.

Blake (2012) suggested that NUIs aim to reuse existing skills that users know inherently, and once they have learnt the skill (for example scrolling), users are able to apply and reuse that skill elsewhere. Participants thought the volume bar was easy to use and appropriate for touchscreens (scroll bar instead of buttons up and down in PRC) and using the natural gestures as suggested by Blake (2012) endeavoured to improve the user experience (guideline 12). This also validates the guideline regarding the use of scroll bars, which is echoed by guideline 9 (Table 7.7). As this was a new prototype that users had never seen before, there was a learning curve. However, it was observed by the researcher, that as users completed the tasks and learnt the gestures they needed to use, they remembered these gestures and later applied their knowledge about the gestures to the tasks required of them. Tognazzini (2007) principles indicate that all devices and systems will have a level of learnability. Using gestures consistently throughout the VRC may help improve users' learnability of the application and may improve their efficiency when using the system (Blake, 2012). This finding confirmed guideline 11 (Table 7.8), and guideline 12 (Table 7.9). This result further confirms that multiple indicators are needed to show what actions (gestures) can be taken to make the users more aware of unknown functionality, for example, include tooltips in the application. Nielsen (1993) suggested that the system should always keep users informed about what is going on, using appropriate feedback within reasonable time. Roto and Oulasvirta (2005) support this view. Visual feedback, such as an auto-tune icon, or a confirmation message to say a favourite has been added, or that language changes were accepted, was needed to confirm users' selections. PRCs were able to give tactile feedback, whereas the feedback given by VRCs is more visual, or felt through vibrations (touching the virtual buttons and the feedback given). These results show the importance of visual cues and feedback to users on their VRC in order for them to know what they can do with the system, and know that the system is responding. These findings confirm guideline 1 (Table 7.1), and guideline 13 (Table 7.10).

Nichols and Myers (2003) suggested functional groupings to construct good UIs. The VRC used well-grouped channels, which made selections easier for users, allowing them to quickly scroll through the channels and instantly see where they had navigated to. This result validates the guideline regarding well-grouped content in guideline 2 (Table 7.2), guideline 11 (Table 7.8), and guideline 15 (Table 7.10). The CTA and brainstorming focus groups' results showed that

users wanted a good search feature, and during the usability testing, users found the search bar and internet to be useful options to get more information with a quick text entry method (QWERTY keyboard). Pan and Ryu (2009) suggested a QWERTY keyboard layout for quick and easy text entry in comparison to the multi-tap keyboard. This finding validates guideline 7 (Table 7.6), and guideline 16 (Table 7.10), regarding simple and quick text entry methods; and guideline 14 (Table 7.10), regarding a robust search function. These guidelines have improved upon PRCs, and the ability for users to find programmes using search, as well as the text entry method used (section 4.2.8).

The results showed that icons such as the question mark, power on/off, star, and the letters 'S', 'E', 'A', and 'B', were concepts that were unfamiliar to some of the participants and, therefore, did not make sense to them. Nielsen (1993) suggested that information should appear logical and natural to the user. Therefore labels should be added to the icons and unfamiliar abbreviations, in order to increase the users' understanding of the VRC, for example, season (S) and episode (E). This result validates guideline 6 (Table 7.5) that says metaphors should be used to help users instantly understand processes, albeit the implementation was not as successful as expected. The addition of a label for unknown icons could perhaps assist users in their understanding of the functionality, which confirms guideline 3 (Table 7.3). Participants expected to add favourites within the favourite channels menu therefore this feature should be adjusted in order to match the expectation of user. This functionality is aligned with guideline 14 (Table 7.10). Nielsen (1993) and Tognazzini (2007) both suggested that user's expectations should be met by speaking the user's language and using concepts familiar to them. As an improvement, tooltips could be used to improve users' knowledge of how to add favourite channels, and auto-tune programmes. The use of 'help menus' or tooltips was questioned in Chapter 5, however, it is apparent that users may still need some guidance for unknown functionality, which reiterates guideline 14 regarding context sensitive help. Icons and labels should be changed in order to match users' expectations of them. For example, the play icon on the PVR list was removed as users expected that when they pressed the play icon, that programme in theory would 'play'. Similarly, a label was needed on the homepage in order to make it clear that users had navigated back to the homepage, since one user, in particular, was unaware of where the home icon took them. These results further confirmed the need to use clear and simple UI titles, suggested by guideline 3 (Table 7.3); quick access routes back to the main screen, suggested in guideline 5 (Table 7.4); as well as icons that match user expectations, suggested in guideline 6 (Table 7.5).

The results showed that minor changes were needed throughout the prototype in order to improve the overall look and feel of the VRC. Spacing between text and buttons needed to be increased to allow for better reading and flow of the information, for example, the text for a programme on the PVR menu and the multimedia player buttons (Chang *et al*., 2002). These results further confirmed the importance of guideline 9 (Table 7.7), which suggests designing stylish and visually attractive UIs; guideline 2 (Table 7.2) and guideline 11 (Table 7.8), that suggest a consistent structure and flow; as well as well-spaced buttons, as suggested in guideline 8 (Table 7.6). These improvements may help to improve the UX.

The results showed that the pop-up information box in the all channels section was disappearing too quickly, and participants wanted to be able to close the pop-up box when they were finished reading the information, giving users more control. Users should be given more control and freedom when interacting with devices, as suggested by Nielsen (1993). This result validates the need for instant feedback however users should have sufficient time to read the feedback given. This was suggested in guideline 4 (Table 7.3) with regards for error messages. However, it did not transpire through the VRC prototype. An improvement to guideline 1 (Table 7.1) can be made in order to allow users to have a certain level of control over the feedback they receive from the system, for example, allowing users to close a popup message once they have finished reading it. A backspace button was needed on the number pad to erase any mistakes users made when selecting a particular channel number, giving users the control to alter their decisions quickly, as suggested by Nielsen (1993), and Shneiderman and Plaisant (2009). This result validates the need for easy reversal of actions, to allow users to explore interfaces as shown in guideline 5 (Table 7.4).

Nielsen (1993) suggests that one should try to minimize the user's memory load. This is done by displaying the channel number within the screen so that the user does not have to remember what channel they are looking at, but rather it should be immediately visible. Placing an add favourites button within the favourite channels menu allows users to select from all the channels available, instead of trying to recall what numbers their favourite channels are, thereby, reducing their memory load. These results validate guideline 3 for LUIs specifying clear and simple UI titles (Table 7.3), as well as using recognition rather than recall to reduce the stress placed on a user's memory in guideline 5 (Table 7.4). This improves upon PRC labelling in section 4.2.5.

The results showed a few inconsistencies within the prototype, which made the users wonder whether similar icons meant different things. Gestures needed to be used consistently throughout

the prototype. For example, tap and hold was used to gain more information, whether it was accessing a popup menu or more information regarding a programme. This reiterates the graphical principles guideline 11, for the use of consistency throughout the VRC (Table 7.8). A separate delete button should be added to allow the 'x' icon to symbolise close and thus resolve the inconsistency issue. Wickens *et al*. (2004) suggests that in order to decrease the chances of confusion for users, it is vital that discriminable icons are used when their functionalities are different. The SUS indicated that all the users would like to use the system (VRC) frequently and that they were satisfied overall with the usability of the VRC. Participants were divided as to whether they thought the system was consistent. All the user testing results indicated that parts of the system, for example, gestures, needed to be changed in order for users to be satisfied with the overall usability, and consistency of the VRC.

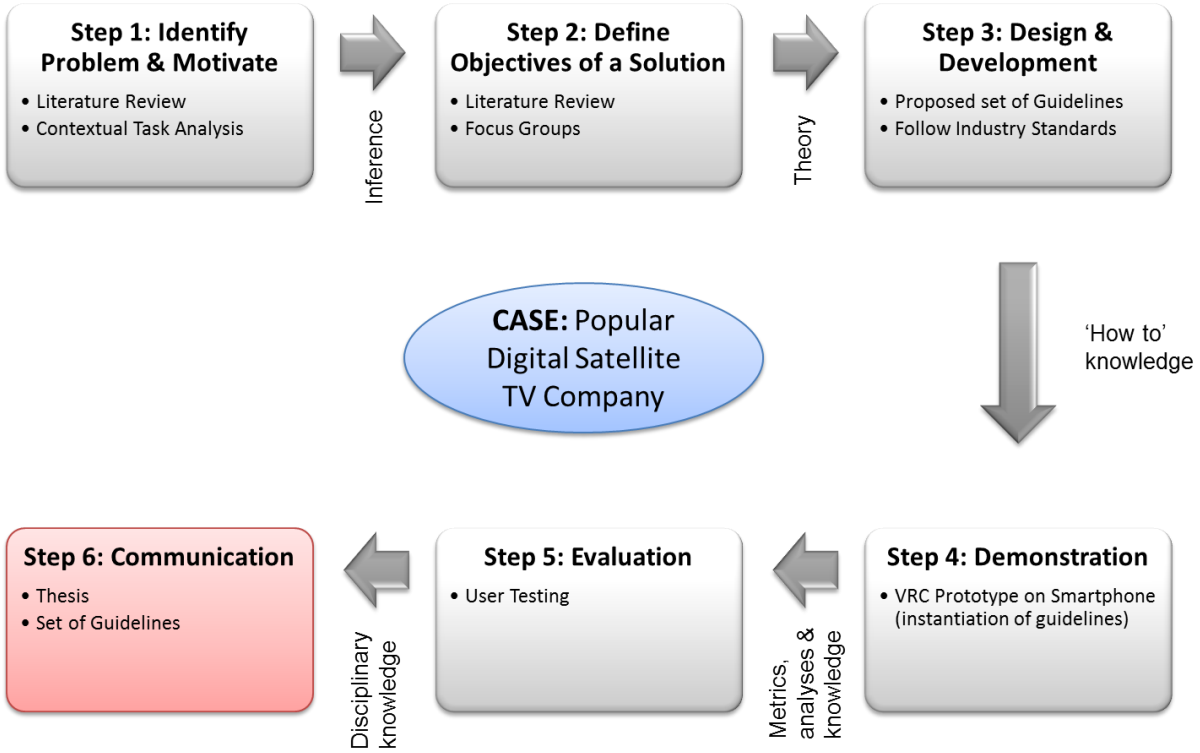
8.6 Conclusion

This chapter focused on the mobile user experiences of users when performing tasks while using a VRC prototype, that applied the user interface design guidelines and functional interface guidelines, as suggested in Chapter 7. Users were observed while completing the tasks and their task successes, as well as user satisfaction levels, were recorded. The proposed user interface design guidelines, informed by the review of literature, CTA, and brainstorming focus groups were used as a means to create the VRC prototype, which was then tested. It can be established that by utilising the underlying usability principles to evaluate the VRC prototype, the users had enjoyable user experiences and the VRC was found to be usable. Overall, the users had an enjoyable user experience with the VRC prototype, which validates the proposed user interface design guidelines. The VRC prototype did fall short of certain users' expectations since it was only a high-fidelity prototype and not a fully functioning application. The visual implementation of a few of the guidelines needed to be improved. In particular, making users aware that they could use specific functionality (gestures), by providing a tooltip to assist them with using unknown functionality (for example, gestures) on varying screens, as well as to improve their knowledge of the system with contextual tooltips. The gestural interface guideline was validated as there was a definite need for multiple visual indicators (guideline 1) and contextual help (guideline 14). An addition to the user interface design guideline 1 is needed to allow users to have a certain level of control over the feedback they receive from the system. For example, allow users to close a popup message once they have finished reading it, instead of it disappearing after a certain amount of time. Overall, the results regarding the user interface design guidelines were successful.

Chapter 9 Conclusion

9.1 Introduction

This final chapter, as well as the entire dissertation, contributes to step 6 of the DSRP model; which relates to the communication of the user interface design guidelines for a usable digital TV VRC, via a touchscreen smartphone that aims to enhance the UX.



In this final chapter, the research results are briefly summarised and communicated with reference to the research questions. The research process used and the contributions made are overviewed, and the chapter concludes with suggestions for future research. The contributions for this research include the user interface guidelines for digital television virtual remote controls via touchscreen smartphones.

9.2 Achievement of Research Objectives

This dissertation used Peffers *et al*. (2007) Design Science Research Process model to structure the research in a phased approach that looked at the single case of a popular digital satellite TV Company. Research question 1, "*What user interface design features should be taken into account when designing for touchscreen devices?*" was covered in Chapter 3. This chapter looked at the domain theory for mobile user experience, mobile human computer interaction, and mobile user interfaces. The findings of Chapter 3 revealed that social factors, cultural factors, context of use, the user, and product, all affect the user experience. Usability principles

(learnability, memorability, errors, efficiency, satisfaction, and effectiveness) should be used as guidelines for measuring MUIs. Mobile user interface design, as defined in this research, comprises four parts, namely: physical; logical; graphical; and natural user interface; from which a set of preliminary user interface guidelines were proposed.

Research question 2, "*What are the current usability issues with physical and virtual remote controls?*" was covered in Chapter 4 and Chapter 5. Chapter 4 looked at the usability issues of PRCs and VRCs, and Chapter 5 completed a contextual task analysis that helped the researcher to understand the context of use in which users operated PRCs, and tasks users completed. Chapter 4 uncovered a list of suggested guidelines for PUI, LUI, and GUI based on the literature that was reviewed. Chapter 5 found that VRCs should cater for usage in relaxed and comfortable environments, with various lighting settings, noise, and external distractions. The CTA established a list of tasks (frequent and troublesome) that users performed when operating their PRCs, and usability issues they encountered, which supported the literature in Chapter 3 and Chapter 4.

Research question 3, "*What user interface design features should digital TV virtual remote controls contain?*" was covered in Chapter 5 and Chapter 6. Chapter 5 looked at what functionality supported users' activities, or negatively affected their user experiences when operating PRCs. This chapter found a list of functional interface guidelines regarding feedback, functionality, information, and buttons. Chapter 6 looked at exploring new ideas for VRC functionality through the use of brainstorming focus groups. This chapter highlighted functionality that users wanted in VRCs, the gestures they were familiar with, and the suggested interface design element that should be used for the various tasks highlighted in Chapter 5.

Research question 4, "*What impact do the user interface design features have on the usability and user experience of virtual remote controls?*" was covered in Chapter 7. This chapter proposed a set of user interface design guidelines, and successfully demonstrated the usage of the guidelines through an instantiated VRC prototype. A total of sixteen guidelines were presented, and a high-fidelity VRC prototype was created.

9.2.1 Theoretical Contribution

This research detailed an effective example of how the Design Science Research Process model can be applied. The mobile user interfaces, namely: physical, logical, graphical, and natural interfaces were better understood and recorded in more detail. The PRC usability issues were

assessed in detail, which created a greater understanding of the issues, as well as the missing elements of PRCs. The information that was extracted from the literature, CTA, and brainstorming focus groups showed a definite need from users for improvement on their existing PRC functionality. It was made clear during the brainstorming focus groups that VRCs should contain all features that already exist in PRCs, with the addition of the functionality suggested by users. This research showed the importance of the entire user experience in relation to PRCs and VRCs. The CTA and usability testing took place in the 'context of use', with users that had various social and cultural backgrounds. This helped the researcher to understand the needs and habits of users, and the way they interacted with the devices. The usability testing confirmed what much of the literature, CTA, and brainstorming focus groups alluded to. The testing showed that all users' experiences are different, and what works for one user might not be the preference of another user. The goal should be to try and create a user interface that can provide most users with the best possible user experience. The main PRC usability issues were an excessive number of buttons, rigid layout (button always available), small buttons, inconsistent use of colour, confusing labels that rubbed off, clumsy navigation, and complex text-entry methods. The PRC usability issues may have been improved through the instantiated user interface design guidelines (VRC prototype); by reducing the number of buttons per screen and only showing the relevant buttons for the actions that could be taken. The sizes of the buttons were increased to be between 7mm and 10mm, which is the standard size for buttons, and colours, were used consistently throughout the prototype. The use of a touchscreen smartphone eliminated the issue of labels rubbing off. Gestures were used for natural interaction with the VRC, and for quick navigation between screens or within a screen. The use of a QWERTY keyboard assisted users in typing text easily.

9.2.2 Practical Contribution

Table 9.1 details the user interface design guidelines that were used to instantiate the VRC prototype, and have proven to be successful. The guidelines are divided into the four mobile user interfaces: physical; logical; graphical; and natural interface, as well as the functional interface guidelines that users required VRCs to have. These guidelines can be followed to create usable digital TV VRCs that enhance the user experience.

Table 9.1: User Interface Design Guidelines

User Interface Design Guidelines
Physical User Interface Guidelines
Feedback
Guideline 1: Immediate aural, visual or tactile feedback should be given to users

• To show that the system has responded to their actions e.g. button depressions
• More than once to be understood correctly
• Within reasonable time:
  ○ < 100ms instantly
  ○ If > 4sec give additional feedback e.g. moving icons
• Give users control over the feedback they get from the system

Logical User Interface Guidelines
Menus
Guideline 2: Menus should be well-structured and well-grouped
• Use the 7± 2 rule for menu items • Well-defined menu and icon labels • Frequently used items first on the menu list • Menus should be simple with shallow levels (hierarchical structures) for easy navigation
Wording
Guideline 3: Provide users with familiar, non-technical language (wording)
• Clear and simple UI titles • Consistent wording • Make use of descriptive wording that is simple and clear to users • Avoid technical jargon • Use correct semantics for words accompanying buttons (icons) • Label the key word first for labels and menu items
Guideline 4: Error messages give users information about what went wrong
• State which error occurred and give constructive help • Use plain language with no technical jargon • Allow for sufficient reading time
Navigation
Guideline 5: Navigation must follow a consistent structure and flow that allows users to explore the interface
• Simple navigation that is not cumbersome • Real-world conventions/metaphors to allow the information to be logical and natural • Use recognition rather than recall to limit stress placed on users memory • Include undo, back or cancel buttons for easy reversal of actions • Provide quick access (shortcut buttons) to frequently used features e.g. home button • Provide unchanging visual cues • Use historical navigation for previously viewed pages • Place frequently used buttons in easy to access places
Graphical User Interface Guidelines
Mental Models
Guideline 6: Features and functionality should be aligned with user mental models
• Use icons for menu items where possible • Use metaphors to help users instantly understand processes • Use metaphors consistently • Follow user mental models to correctly group functionality

- Group buttons across different screens for situation dependent variables
- Use the standard numeric (telephone) layout for numeric entry

Buttons

Guideline 7: Buttons (icons) should clearly communicate the content they represent

- Button sizes between 7mm and 10mm
- Keep the number of buttons to a minimum
- Use large buttons for important features
- Use uncomplicated, simple buttons
- Use varied shape buttons, for example squares and circles
- Use colours and appealing designs to make buttons more attractive
- Hide or remove non-essential buttons from screens
- Avoid cumbersome text entry methods. A quick and simple text entry method is needed

Guideline 8: Button placement and positioning should be consistent that allows for quick thumb navigation

- Use good spacing between buttons
- Left position on screen for smaller buttons
- Right position on screen is more suitable to buttons
- Frequently used buttons should be placed in the centre
- Lower right areas on screen are harder to reach

Screen Display

Guideline 9: The user interface screen display should be kept simple, consistent and uncluttered

- Visually attractive and balance simplicity and functionality
- Ensure permanent labels are used
- Give good default designs for a single coherent experience
- Ensure correct input objects are used, for example a dropdown
- Include prominent ‘signposts’ that assist users with easy navigation
- Provide visual cues for scroll bars
- Use a combination of horizontal swipes and vertical scrolling for navigation
- Use a simple layout that is flexible to changes and updates
- Design a stylish, intuitive UI layout that is easy to use and learn

Guideline 10: Contrasting colours and large font sizes should be used to improve legibility between labels and the background colour

- Include a readable typeface and large font size
- Colours should be used consistently for buttons and labels
- Keep colours consistent with those in the real world, for example red for a power button
- Make use of brightness, redundant signals, location and shape, to help colour deficient users

Graphical Principles

Guideline 11: Consistent graphical principles and grouping should be applied

- Minimise the number of screens and button presses
- Clearly map buttons in positions conducive to their functionality
- Consistency should be employed throughout the GUI
    - Through user behaviour
    - Invisible structures
    - Be visually inconsistent when features are different
    - Be visually consistent when features are the same
    - Predicting user expectations
- Elements displayed closer together are grouped as one whole
- Elements that have similar attributes are grouped together
- Users prefer greater symmetry

Natural User Interface Guidelines
Gestural Interfaces
Guideline 12: Gestures used should be natural actions that users are familiar with in order to increase their interaction
• Use multiple indicators to show what actions can be taken
• Rapid instant responses to touch
• Appropriate gestures for different situations, for example tap, tap and hold, pinch, swipe, and scroll
• Use playful engaging gestures that allow for exploration of the system
Functional Interface Guidelines
Feedback
Guideline 13: Give users appropriate feedback on the expected interface
• Display all feedback on second screen (not the TV), for example extra programme information and reminders
• Include visual or aural banner and auto-tune reminders
Functionality
Guideline 14: Give users simple functionality that allows them to easily interact with the remote control
• Allow users to customise their channels into a favourites list
• Include a robust search function
• Give users context sensitive help
• Settings should be simple and uncomplicated
• Provide users with a manner of alternating between multiple channels
• Provide multiple ways for users to change channels
Information
Guideline 15: Organise the information shown to users in a logical format
• Provide users with a TV guide that gives them enough information about the TV programmes
• Give users the ability to acquire additional information from external sources (internet)
• Provide users with a simple way to access more information, for example an information button
• Group information by logical genres
Buttons
Guideline 16: Provide users with quick and easy to access buttons
• Use shortcut buttons for frequently used functions
• Allow for numeric input to change channels quickly
• Make the volume control easily accessible, include a mute button for quick volume control
• Most buttons should only have one purpose
• Use icons for quick access to functionality, for example channel icons, help, volume
• Include the QWERTY keyboard for simple text entry

9.3 Limitations

The major limitation for this research was that only one digital TV provider was looked at, and the user interface design guidelines were applied to this one use case. The limitation is that the results may differ for other digital TV providers.

9.4 Future Research

The following areas can be investigated in future research:

- The use of speech input as a means to control the VRC on a smartphone.
- The application of the guidelines to virtual remote controls in varying countries.
- Further explore the cultural effects of the VRC in South Africa across different languages.
- Application of the guidelines to other digital TV VRCs.
- Explore the impact of technical literacy and functional literacy on the overall user experience when using VRCs.

9.5 Concluding Remarks

The research aimed to develop a set of user interface design guidelines for digital TV virtual remote controls. The Peffers *et al*. (2007) Design Science Research Process model was used to organise this dissertation following various research methods, namely: a review of literature pertaining to mobile user experience; mobile human computer interaction; physical remote controls, and virtual remote controls; contextual task analysis; brainstorming focus groups; and usability testing. The sixteen user interface design guidelines covered the main concepts of the MUI with specific implementation and suggested criteria for each guideline. The guidelines were validated through the usability testing, and an additional point was added to guideline 1, allowing users to have a certain level of control over the feedback they receive from the system. It was confirmed that the set of sixteen user interface design guidelines as defined in this research, within the sample taken, created a usable digital TV VRC, and ultimately a successful mobile user experience. Finally, the study answered the following main research question:

What user interface design features will contribute towards an enhanced user experience for digital TV virtual remote controls?

Not only was the main research question answered, but the rigorous research ensured that the guidelines created for this study can be used by other researchers to build upon, and create, usable user interfaces for future digital TV virtual remote controls, in order to create successful user experiences.

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Appendices

APPENDIX A

RHODES UNIVERSITY

CONSENT FORM

Department of Information Systems

Project Title: User Interface Guidelines for Digital Television Virtual Remote Controls

Researcher's name: Ms Alicia Wentzel

- I have received information about this research project.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage.
- I understand that my participation in this study is done on a voluntary basis.
- I understand that the my interactions with the system will be recorded for later analysis
- I understand that while information gained during the study may be published, I will not be identified and the results I provide will remain confidential.
- I understand that I will receive no payment for participating in this study.
- I am over eighteen (18) years of age.

Name of participant: .....

Signed: ..... **Date:** .....

I have provided information about the research to this participant and believe that he/she understands what is involved.

Researcher's Signature: ..... **Date:** .....

APPENDIX B

Participant	Overall Impression/Wrap-up/Quotes
P1	The user likes that the main screen is basic, not too complicated and simple The user said "*the buttons are a good size*" The user really liked the last viewed bar and thought it was extremely useful The user liked the placement of the number pad, and thought it was highly visible The user got frustrated when the prototype scrolling feature was not working correctly The user preferred the TV Guide layout on the VRC than the one on the usual TV screen saying "*the VRC TV guide is simpler and more effective*" The user liked the layout of the settings and said they were "*clear, self-explanatory and easy to understand*" The user liked that all the actions (tasks) happened on the mobile phone itself The user liked the scrolling, it was far more quicker and natural than using buttons to find the correct information
P2	The user liked the size of the buttons and that the button labels were self-explanatory The user thought the last viewed bar was "*very cool especially if it is scrollable*" The user liked the positioning and colour of the volume bar The user liked that they could see what was currently showing on another channel without changing the channel The user enjoyed being able to scroll through the screen The user liked that many TV programmes were displayed in the specific channels on the TV guide The user liked that the layout of the TV guide was easy to read and scroll through The user liked that the settings was a list and it was "*nice and simple*" The user enjoyed that everything was on the mobile phone and it was simple to use
P3	"*The home page is fairly clear, well set-out and looks pretty simple*" The user thought the button label sizes and colours were good The user liked that the time would be shown on the VRC The user thought the names of the buttons were clear and the user would know what to find under each label The user said that once they had learned which gestures to use to gain more information they would remember these gestures throughout the application The user liked that the icons looked really modern but said the tabs looked too simple The user liked that the channels were grouped into categories The user said, "*I really like the last viewed bar and think it is cool*" The user said, "*This is brilliant, I am so excited*" (talking about the VRC) The user liked the slider for the volume bar and said it was appropriate for touchscreen, even though the user preferred to use the buttons on the PRC The user thought the settings were simple and good and that it is "*spelt out for you*" The user thought it was better having the features on the mobile phone since it was a lot closer and the user could see the smaller details
P4	The user thought the home page was clear and liked the style and size of the labels, saying "*it does not need the decorations, the simpler the better"* The user liked that there were less buttons than the PRC, since they did not even use 90% of the features (buttons) currently The user liked the relative uniformity of the design The user liked the scrolling and that the screens were not clouded by too much artwork

	The user enjoyed the thematic groupings of the icons The user thought the last viewed bar was "*nice and very handy*" The user liked the text size, in the PVR options, and thought the font was clean and simple and liked that there was white text on a black background The user thought changing the settings on the VRC was "*straight forward and easy*" The user felt more inclined to explore the features on the VRC than on a PRC The VRC seemed user friendly even to a novice user The user raised concern about whether they could operate more than one VRC in a household
P5	The user said the first screen was informative and clear The user liked that the buttons were big since they could press them quickly without having to aim The user thought the last viewed was useful in terms of speed The user thought it was useful to get extra information about the programme a user was watching by accessing the internet link on the page The user thought it was "*great to have all the channels under different headings to make the selection easier*" The user said they would use the search feature to find specific programmes The user had never changed the language using the PRC before but thought the VRC process was very simple The user thought the VRC was exciting and different and a good idea The user asked if the mobile phone would be moved around the room and thought this may be a problem The user did like that the VRC was on the mobile phone, that is was accessible, portable and easy to access
P6	The user liked that the home page displayed all the information they needed to know The user liked that there were minimal buttons on the home page (only five options) The user said once they knew to do certain gestures to access information they would remember which gestures to use The user liked the number of icons available on screen and said, "*I would not even allow for an option to add or remove buttons"* The user liked the last viewed panel which made it easier to switch between channels The user said they would use the website link to check the ratings of movies and age restrictions The user liked that the search bar was available to sift through more data and said "*it is vital that there is a good search feature*" The user did not want the UI to become overcomplicated "*the simpler the better*" The settings were clear and simple and the user did not want them to be complicated
P7	The user liked the size and colour of the buttons on the home page, the user liked that they were plain and accessible The user liked that the icons displayed the number of the channel as well as an image The user thought the last viewed bar was "*a great feature*" The user liked that the time and signal would always be available The user liked that they had the ability to switch between the TV guide, news and weather options The user preferred the list option in the settings menu, saying "*it is very simple and easy to use*" The user thought the VRC was simple and uncomplicated The user thought it was great that the VRC was on the mobile phone The user said they would find it difficult to type the numbers of the channels into the number pad quickly since the user could not feel the buttons

APPENDIX C

Guideline	Task	Area/Location	UI Design Issue	Participant	Suggestions from Participants
GUI – Graphical Principles	Task 1	Home Page	User thought the help button was only related to volume due to its position Unsure what the question mark was for	P3, P5, P7	Increase space between help button and volume Give the help button a label
GUI – Screen Display	Task 1	Home Page	Buttons on home page do not have impact	P3	Make buttons more colourful and make the buttons 3D
GUI – Screen Display	Task 1	Home Page	Letters for button labels were normal	P1, P3, P4	Make labels on buttons bold
GUI – Mental Models	Task 1	Home Page	User did not know the universal sign for power on/off	P6	Label the power button to make it clearer
GUI – Screen Display	Task 1	Home Page	Power button graphics look blurry	P7	Improve the power button graphics
GUI – Graphical Principles	Task 1	Home Page	User didn't like that the buttons were an uneven number	P7	Place a graphic or button in the empty space Place a 'favourites' tab in all channels to remove the button from the main screen
PUI - Feedback	Task 2	All Channels	Pop-up information box, showing programme information for the channel, disappeared too quickly	P1, P2, P4, P5, P6, P7	Allow users to exit by themselves with an 'x' in the top left corner Increase time it takes for pop-up information box to disappear
LUI - Navigation	Task 2	All Channels	Users were not aware that they needed to press and hold the channel icon to get more information about the programmes being shown on that channel	P1, P2, P3, P4, P5, P6	A tooltip (with the option to never be shown again once it has been read) to show users the various ways in which they can access all features

LUI - Wording	Task 2, Task 4	All Channels	No channel number displayed in the information pop-up box	P5	Display channel number in the information pop-up box
GUI – Mental Models	Task 2	All Channels	Unsure of what the website link was for, due to not knowing the website name	P5, P7	Allow users to type in their own website address that they wish to visit The website search bar should always be accessible at the top of the page
LUI - Navigation	Task 3	NumPad	No backspace button on number pad	P3, P7	Place a backspace button on the left of the zero
GUI – Graphical Principles	Task 1, Task 2, Task 3	All Channels	Images and logos seem a bit disjointed/disconnected from each other	P2	Change shape of icon (image and number) to a rounded shape to group the two together
LUI – Navigation; GUI – Screen Display	Task 1, Task 2, Task 3	All Channels	Users were unsure if they needed to scroll up/down or left/right (no visual indicators)	P1, P2, P3, P4, P6	Place a scroll bar icon on the side of the screen to indicate scrolling
LUI - Wording	Task 1, Task 2, Task 3	All Channels	User thought music label was for the music TV programmes and not audio music	P1	Change label to audio
GUI – Screen Display	Task 1, Task 2, Task 3	All Channels	Heading for the channel categories is not noticeable	P1, P3	Increase the heading label font size and make the label bold Centralise the heading label
LUI – Navigation; GUI – Mental Models	Task 1, Task 2, Task 3	All Channels	Unsure where the home button took the user	P4	Place the title Home Page on the home page with the icon to indicate to users that it is the home page
GUI – Screen Display	Task 1, Task 2, Task 3, Task 4, Task 5, Task 6, Task 7, Task 8	All Channels, Favourites, TV Guide, PVR Menu	Tabs and buttons look too plain and simple	P3, P6, P7	Improve the appearance of tabs and buttons to be more updated and highlighted when selected
LUI - Navigation	Task 4	TV Guide	User unsure which gesture to use to gain more information (scrolling, press and hold, tap)	P2, P5, P6	Use gestures consistently

LUI - Wording	Task 4	TV Guide	Unsure what the S and E meant on the programme information page	P4, P5	Write out the full words for season and episode space permitting
GUI – Mental Models	Task 5	TV Guide	User unsure of how to auto-tune the channel User thought 'A', 'B' were synchronicity items didn't associate it with the word	P2, P4, P5, P6, P7	Tap and hold the channel in, a pop-up menu appears with auto-tune/banner/record options Show an image of a banner for 'B' or put the full word Show a tooltip of how to auto-tune to a programme
PUI - Feedback	Task 5	TV Guide	Not clear if the programme will be auto-tuned	P1, P2, P3, P4, P5, P6, P7	Visual feedback needed, display an 'A' next to the text of the programme being auto-tuned (similarly with banner and record)
GUI – Screen Display	Task 5	TV Guide	Not enough programmes displayed for each day in the TV guide	P2, P6	Implement a swipe gesture to swipe across the entire list of the day's programmes on the particular channel and the next day's list of programmes would be displayed for that particular channel
LUI – Navigation; GUI – Mental Models	Task 4, Task 5	TV Guide	Disjoint between 'All Channels" and 'TV Guide'	P2	Make an access point available in 'All Channels' for the user to get to the TV Guide
LUI - Navigation	Task 4, Task 5	TV Guide	No back button on the screen (there was a back button on the actual device)	P2, P3, P5	Place a back button on the screen Use a tooltip to make the user aware of the back button on the device
GUI – Buttons, Screen Display	Task 4, Task 5	TV Guide	Weekday labels/tabs too small	P6	Increase the size of the labels and tabs
GUI - Buttons	Task 4	TV Guide	Only QWERTY keyboard option for search bar	P7	Give users the option to switch between a multi-tap keyboard and QWERTY keyboard
GUI – Mental Models, Screen Display	Task 6	Favourites	User did not know what the star icon represented	P1, P3, P4, P5, P7	Give a tooltip to inform user what the star means Insert a 'add to favourites' button Include a favourites label close to the star icon
PUI - Feedback	Task 7	Favourites	User was unaware that favourite channel had been added when	P1, P4, P5, P6	Need feedback to confirm that channel has been added to favourites

			pressing star icon		
GUI – Mental Models	Task 6	Favourites	User was unsure how to add a favourite	P1, P3, P4, P5, P6, P7	In the favourite channels section, make an 'add favourites' button available, when pressed a list of all the channels appears and the user selects each channel they wish to make a favourite Press and hold a channel icon down in the 'All Channels' section, a pop-up menu appears with the option to 'add favourite' Use a tooltip to tell the user how to add a favourite Press and hold the channel down in TV Guide and a pop-up menu appears with options to add a favourite
GUI – Mental Models, Graphical Principles	Task 7	Favourites	Unsure how to delete the favourite channels once they had been added	P3	Press and hold the favourite channel down, then a pop-up box appears with the option to delete the favourite channels
GUI – Mental Models	Task 8	PVR	Expected programme to begin playing immediately	P1, P2, P3, P4, P5, P6, P7	Change the play icon, or remove it completely from the programme list
GUI – Mental Models	Task 11	PVR	Expected 'x' on programme label to close the programme	P2, P3, P4, P6, P7	Use 'x' consistently Sensitise the 'x' to another colour or style to show it is delete and not close
GUI – Mental Models, Buttons	Task 11	PVR	Unaware of how to delete programme	P1, P2, P3, P4, P6	Press and hold the programme down, then a pop-up menu appears and the programme can be deleted Delete button
LUI - Wording	Task 11	PVR	Too many words in the delete programme pop-up box	P5	Decrease the number of words in the pop-up box
GUI – Screen Display	Task 8	PVR	Tab buttons too squashed	P1, P3	Increase the space between the main tabs
GUI - Buttons	Task 8	PVR	Multimedia player buttons too	P1	Increase the size of the multimedia player buttons

			small		Increase the size of the play button and make it rounded and green
LUI – Wording; GUI – Screen Display	Task 8	PVR	No dates or episode numbers displayed on the list of programmes in PVR	P2	Display the date and episode numbers on the list of programmes in PVR
GUI – Screen Display	Task 9	PVR	Text too close together	P3	Increase space between text for programme description
GUI – Screen Display	Task 8	PVR	Multimedia player buttons and scroll bar too close to each other	P3, P4, P5, P7	Increase space between multimedia buttons and scroll bar
GUI - Feedback	Task 12	Settings	Unaware if the language changes had been accepted	P1, P4, P5, P6	Place a tick next to the language setting selected Pop-up box confirming the changes Close the languages option screen and return to main settings menu Place an 'apply' button on screen to apply the changes to the language settings
LUI – Menu, Wording	Task 12	Settings	Unsure of what 'information' would entail in the settings menu	P2	Place the word technical in front of 'information'
GUI - Buttons	Task 1, Task 2, Task 3, Task 4, Task 5, Task 6, Task 7, Task 8, Task 9, Task 10, Task 11, Task 12	Home Page, All Channels, Favourites, TV Guide, PVR, Settings	No need for power button to be available all the time	P7	Place power button on the Home Page only