Gaze patterns of expert and amateur sight-readers with particular focus on the cognitive underpinnings of reading key and time signatures

by

J. F. Viljoen
619V7651

A thesis submitted in partial fulfilment of the requirements of the degree

PhD (Music)

Supervisor: Professor Catherine Foxcroft

July 2021

0000-0002-0524-7120

Abstract

Over the last decade, eye-tracking technology has provided researchers with specific tools to study the process of reading (language and music) empirically. Most of these studies have focused on the “Eye-Hand Span” phenomenon (the ability to read ahead of the point of playing). However, little research investigates the cognitive implications of specific aspects of musical notation when performed in real time. This research aimed to observe the fixations patterns of sight-readers in order to investigate the cognitive underpinnings of key and time signatures in music scores.

This research project is a quantitative study using a quasi-experimental research design. Tobii eye-tracking equipment and software were used to record the eye movements of 11 expert and 7 amateur keyboard sight-readers. Two key aspects of music notation, key and time signatures, were selected as the main focus of the study. To investigate these aspects, eighteen research participants were provided with seventeen sight-reading examples for one hand (low complexity) and two hands (high complexity) composed specifically by the researcher. Several examples contained one or more unexpected aspects (accidentals or changes of time signature) to test their effect on fixation count and duration. Two variables (fixation count and fixation duration) were utilised to analyze fixation patterns on the selected aspects of the scores.

Three main results emerged from the data analysis: 1) Expert sight-readers performed with much greater accuracy than experts in both tests; 2) Expert sight-readers exhibited a higher fixation count on entire scores in complex examples; 3) Both expert and amateur sight-readers fixate more and for longer on certain notational aspects such as key and time signatures than other notational aspects such as deviations or individual notes. This selection of focused attention suggests that both expert and amateur sight-readers cognitively process music scores in a hierarchical order.

In conclusion, key and time signatures appear to require more and longer fixations by both groups of readers than other aspects of the score. This supports previous research which suggests that sound musical knowledge may play a positive role in performers’ sight-reading skills, thereby contributing to more successful sight-reading performances.

Keywords: cognition, eye-tracking, musical notation, sight-reading.

Dedication

This study is dedicated to the most important person in my life, my amazing wife. Thank you for your support and understanding. Thank you for being the most incredible partner and companion. Thank you for all the listening and advice during this long process. This is for you.

Acknowledgements

I would like to acknowledge the contribution of the following individuals:

- Professor Catherine Foxcroft for your amazing support and supervision.
- Dr Boudina McConnachie for your guidance through the ethics process.
- Emmerentia Emmerich for your Tobii expertise, all the help during data collection and all the support during the writing process.
- Inclusive Solutions for so generously giving us access and use of the eye-tracking equipment.
- Phillip van Niekerk for the statistics.
- Professor Alethea de Villiers for granting me permission to conduct research using students from your department, your continued support and always offering advice so freely.
- Dr Erika Bothma, Dr Tinus Botha and Dr Ben Schoeman for advising on the composition of the sight-reading examples.
- To all of the participants for bravely coming to perform sight-reading exercises during data collection.

Contents

List of Figures

List of Tables

List of Appendices

Chapter 1 – Introduction

1.1 Background and rationale

Most research relating to eye movement focuses on general behaviour and language (reading and cognition). Recently, sophisticated technological advances in eye-tracking equipment have provided researchers with the means to record and interpret eye movements in order to understand the link between eye movements and cognition. Research suggests that 'seeing' is "inextricably linked to cognition", that humans have to learn where to look in order to find the necessary information, that our ongoing cognitive goals seem to "orchestrate" our gaze patterns and that our gaze patterns seem to be linked to an internal reward system (Hayhoe & Ballard, 2005, pp. 188 - 191). Wilming et al. (2017) propose that the oculomotor system constantly selects which parts of the environment should be processed. Our gaze patterns seem therefore to be directly linked to our cognitive goals.

According to Madell & Hébert (2008, pp. 157 - 158), our gaze patterns can be classified into fixations and saccades. Fixations are relatively short stationary pauses "during which information is communicated to the brain" while saccades are extremely swift movements "during which information is suppressed" (Madell & Hébert, 2008, p. 158). Saccades can be classified further as regressive and progressive saccades. During progressive saccades, the reader moves forward to obtain information, while regressive saccades take place when a reader wants to "recover information or improve comprehension" (Cara & Vera, 2016, p. 3). Puurtinen (2018a, p. 1) says that "in practice, during one fixation, we only see a few note symbols accurately and everything else in our visual array remains blurred. With a saccade, we then move our area of accurate vision to fixate on the next note symbols, and to see them clearly".

Some of the earliest research regarding music sight-reading, eye movements and cognition was conducted by John Sloboda (1974, 1984). Although his studies are technologically dated, he made some remarkable discoveries regarding reading music notation. Sloboda (1984, p. 235) claims that music reading is a "genuine species of music perception". Expert sight-readers (musicians who demonstrate a fluent reading ability of music scores) seem to possess the ability to mentally perceive the music before attempting a performance. Sloboda argues that this ability is formed by an understanding of musical structures. Furthermore, expert sight-readers exhibit the ability to read ahead of the point of performance, a phenomenon referred to as the eye-hand span (Sloboda, 1984, p. 230). Subsequent research suggests that expert sight-readers' eyes are drawn even further forward when visually complex material or deviations from expected patterns occur in the score (Huovinen et al., 2018, p. 21). Most of the studies focusing on sight-reading have been limited to keyboard sight-reading.

It is important to distinguish between sight-reading a new score without prior preparation and reading a music score after a short period of preparation. While most studies refer to their research topic generally as pertaining to "sight -reading", the conditions of their research differ in one significant aspect (Puurtinen, 2018a, p. 8). Some researchers like Huovinen et al. (2018) present their participants with the music in real time, requiring their participants to read as the music is presented. Others, like Goolsby (1994), present their participants with the music and a window of time to rehearse the music. A performer would be quick to point out that these are two vastly different performance scenarios. This study will mainly focus on participants performing music after a very brief period of viewing (four seconds), as this is the closest scenario to the conditions of musicians in the professional world.

The complex task of reading music appears to present the reader with additional challenges not necessarily found in text reading. The first of these challenges is that music reading (and subsequent performance) adds a temporal component, which means that the music must be read within a certain timeframe (Puurtinen, 2018a, p. 11). Any hesitation in the reading and performing process will disrupt the natural flow of the music. In addition, the fact that music sight-reading is performed means that the brain is also required to process "motoric" components (Puurtinen, 2018a, p. 1). This implies that cognitive processes are strongly linked to subsequent physical responses on an instrument.

Puurtinen (2018a, p. 7) argues that it is vital that future studies in the field of eye-tracking and music reading should consider these two complexities (namely the temporal and motoric challenge of music reading) and use methodologies with greater consistency. Some studies, like Cara & Vera (2016) did not require any performance from their participants, while others like Huovinen et al. (2018) required their participants to perform their musical examples and discarded many of these based on accuracy of performance. Huovinen et al. (2018) also specified a metronome mark (speed) for each example to be performed. Puurtinen (2018a, p. 7) says that it is vital for studies to make an effort to control the performance tempo of their musical examples. If the tempo of an extract is not specified and controlled during a performance, a less experienced reader might choose a slower tempo and perform with as much accuracy as a skilled reader playing at a much faster tempo. This study specified and controlled the tempo (by means of a metronome) for each example.

One of the first studies to utilise eye-tracking technology in the practice of reading musical notation was done by Goolsby (1994). Supporting Sloboda's Eye-hand span theory (without the use of technology), he further suggests that skilled sight-readers read further ahead in the music and with much more accuracy than unskilled sight-readers. In addition, he claims that expert sight-readers group certain notes or features of the score into patterns when reading. Less experienced sight-readers read every note, while experts fixate on patterns instead (Goolsby, 1994, p. 121). Other researchers (Arthur et al., 2016, Saxon, 2009, Wolf, 1976) concur, proposing that these patterns can be measured as they are achieved by "fewer fixations of shorter duration" (Arthur et al., 2016, p. 2) and that expert sight-reading is simply a matter of expert pattern recognition (Wolf, 1976).

Expert sight-readers may also use their knowledge of musical structures to correct errors in scores, as well as fill in missing information (Drai-Zerbib et al., 2011, p. 219). This implies that expert sight-readers rely heavily on memory structures, suggesting that a thorough knowledge of musical structures is required in order to excel at sight-reading. This discovery is significant, as it seems to indicate that there are recognisable patterns embedded into the music score that experts can instantly identify and respond to. These patterns may range from simple melodic scale patterns, intervals, tonality, and rhythmic patterns, to larger form structures, and harmonic progressions. Cara & Vera (2016) state that these patterns are recognised in a particularly sequential way, influenced by the melodic shape and texture of the music. Thus, the ability to recognise and respond to these patterns requires an understanding of the theoretical concepts involved as well as diligent practice (Last, 1972).

As a music educator, the researcher teaches piano and piano sight-reading to students on a daily basis. Although numerous researchers suggest a number of theoretical strategies regarding sight-reading, music educators still express a need for improved, effective sight-reading strategies that will help students develop their own sight-reading abilities. In a recent methodological review of music reading eye-tracker studies, Puurtinen (2018a, p. 13) calls for greater consistency in music reading studies as well as studies aimed at understanding how the basic aspects of music reading and cognition occur. As Madell and Hébert (2008, p. 159) state:

> because the cognitive underpinnings of the reading process are unknown, it is difficult to know the best teaching approach and to assess its efficacy in normal readers. In addition, it is almost impossible to find the locus of the problem in those who are experiencing difficulties, and hence to suggest a remedial strategy.

This research investigates how sight-readers approach two specific aspects of cognitive processes involved in music sight-reading: time and key signatures, with the aid of an eye-tracker. To the best of the researcher's knowledge, very little research has been done in this area. Findings of this empirical study could add new insights into the cognitive processes that occur when sight-reading music through providing analyses drawn from technologically based data. This may provide music educators with updated approaches to effective teaching strategies of sight-reading skills.

1.2 Aims of the research

This study aims to explore how two basic aspects of music notation sight-reading, namely key signature (signifying tonality) and time signature (signifying meter) are cognitively processed by expert and amateur sight-readers. These two aspects were selected because of their particular significance in Western tonal music. Most musicians suggest that these two aspects receive a lot of their attention while reading music, however in practise, it may not be the entirely true. Using gaze patterns, the study will analyse and compare the fixation patterns of expert (skilled) and amateur (unskilled) sight-readers when sight-reading music extracts containing a range of key signatures and time signatures. The use of eye movements as a method of studying cognitive processes was selected as it has proven successful in several music reading studies. The study further aims to explore deviations in the score (accidentals and changes in meter) as these may offer further insights into the cognitive processes involved in reading key and time signatures.

1.3 Research questions

The main research question is:

What are the cognitive underpinnings of reading key and time signatures in a music score?

Sub-questions:

The sub-questions of the research question are:

- How do expert and amateur sight-readers' fixation counts and fixation durations compare when reading key and time signatures?
- How do expert and amateur sight-readers' fixation counts and fixation durations compare when reading score deviations (accidentals and changes of time signature)?

1.4 Methodology

This study makes use of quasi-experimental quantitative research designs, as these designs are used to explore and describe relationships between phenomena (McMillan & Schumacher, 2010, p. 222). A descriptive, comparative design will enable the researcher to describe the visual patterns recorded for both participant groups, as well as compare the results for each group.

Measures were put in place to ensure objectivity and reliability of results. These measures included:

- A standardised protocol to ensure that participants were exposed to the same conditions.
- A panel of experts was consulted to determine the areas of interest in each musical example measured by the eye-tracker. These experts were selected from university piano lecturers in South Africa, as they needed to have experience in the field of assessing sight-reading performances.

- A metronome was utilised to control the tempo of performances.
- An independent, objective measuring instrument (eye-tracking and Tobii software) was used to assist with data collection.
- An expert interpreted the data.

1.4.1 Participants

Eighteen participants were selected for two research groups through convenience sampling. Advantages of this method of sampling include easy administration, time effectiveness as well as low associated cost. It also makes generalisations possible due to similarities between participants. Disadvantages include a likelihood of error due to bias, reduced external validity and being less representative of a specific population (McMillan & Schumacher, 2010, p. 137).

The participants were selected from music teachers in Grahamstown (Makhanda) and Port Elizabeth as well as students from Rhodes University and Nelson Mandela University. They were contacted via email or telephonically.

1.4.2 Materials and equipment

After agreeing to participate in the research project, a standardised sight-reading test selected from the Trinity Guildhall Grade 6 piano syllabus was presented to each participant to determine the Group A (expert) locations. Group B (amateur) consisted of amateur sight-readers who failed to accurately perform the standardised sight-reading exercise. Group A (expert) consisted of skilled sight-readers who accurately performed the exercise. Participants needed to score 80% or above for the exercise based on Trinity College sight-reading rubric in order to qualify for Group A (expert). Any performer scoring a lower mark was assigned to Group B (amateur).

During the research, seventeen musical extracts were presented to each participant on an electronic display device. These examples included various time signatures, key signatures and tempo (speed) indications as well as different clefs. A metronome was utilised to indicate tempo to participants.

A Tobii X2-60 Hz eye-tracker and Tobii Studio software were used to measure the variables of interest. This method of data collection has been used before in studies like that of Arthur et al. (2016) and Cara et al. (2016). The monitor was mounted on a height-adjustable floor stand to accommodate different seating heights of participants.

The selected musical extracts were presented in a random order on a monitor (with the clip-on eye-tracker-attached) using PDF document format. Each extract was presented to the participant, allowing four seconds of reading time.

A procedural protocol checklist was used to ensure procedural reliability for each participant.

A video camera was set up behind the participant to record the performance. This was used to assess the success of each performance after data collection.

1.4.3 Data collection

Data collection was done using Tobii eye-tracking research technology recording the participants' gaze patterns when viewing the musical extracts. The data were collated in the Tobii Studio Software application for analysis. The described method of data collection has low inference and is therefore reliable and objective.

Prior to data collection, the eye-tracking equipment was set up in a designated quiet room. An electronic piano was placed in the room, on which participants performed the musical extracts. A metronome was also used to indicate the tempo (speed) of each extract played.

The Tobii Studio software allows for the identification of areas of interest (AOI). The key and time signature of each example was selected as AOI A, while all deviations were isolated as AOI B. Two further notes (G and T) were identified as AOI C and acted as a control aspect. G was the first note of bar five in Test 1, as well as the first note of bar three in Test 2. T was a randomly selected tonic note from each example.

A profile was created for each participant, which stored calibration settings and results, as well as other data specified by the researcher. Each participant's performance was recorded using a video camera to measure performance accuracy. All instructions regarding the procedure for each participant were explained prior to viewing of musical extracts.

1.4.4 Data analysis

Variables needed to be defined before analysis could commence. The Tobii Pro X2-60 has a sampling rate of 60 point-of-gaze recordings per second. This means it can obtain a point-of-gaze sample every 16.6ms (Tobii Technology, 2010, p. 6).

The following variables were identified and measured by the eye-tracker and software:

- The number of fixations
- The duration of fixations

The data collected were summarised by means of descriptive statistical techniques. This aimed to transform the numbers into descriptors and characteristics of the data (McMillan & Schumacher, 2010, p. 149).

Measurement validity was ensured through a nine-point calibration process that was completed with every participant before data collection commenced. An expert analysed the data for the researcher.

1.5 Definitions of key concept and terms

This section provides a list of the key terms or concepts used in this study. These are outlined here to provide the reader with a clear set of definitions for all these terms, some of which are used frequently throughout this study. This section also provides the reader with a source of reference for these terms.

Table 1 Key terms

Term	Meaning
Fixation	Stationary pauses of eye movements in which the brain absorbs information
Saccade	Rapid shifts of eye movements in which the brain processes information
Area of interest (AOI)	Term used by Tobii Studio Software to identify a selected area used in data analysis
Deviation	An aspect in a score that deviates from the expected harmonic or tonal patterns. In this study, accidentals and changes of key signatures are referred to as deviations.
Perceptual span	The ability to process information ahead of a fixation
Parafoveal information retrieval	Another term for perception span

Oculomotor system	Interconnected regions of the nervous system that control eye movements
Eye-hand span	The distance between reading and performance in sight-reading
Scalar melodies	Melodies consisting mostly of stepwise motion using a particular scale
Triadic melodies	Melodies consisting mostly of skips or jumps based on particular chords or triads
Audiation	The ability to hear a word or note before performing it
Initial fixations	First fixations directed to a score
Regressive fixations	These fixations occur when a reader looks back at a particular area of a score
Gaze plot	A visual method of data depiction, showing the order of fixations as they occur in the reading process
Heat map	A visual method of data depiction, showing the location and duration of fixations
AOI A	All data collected for key and time signature aspects of examples
AOI B	All data collected for deviation aspects of examples
AOI C	All data collected for two rule-based selected notes. G is the first note of bar 5 in Test 1 and the first note of bar 3 in Test 2. T is a randomly selected tonic note.

1.6 Chapter outline

Chapter 1 – Introduction
The theoretical context of the study is introduced, along with a summary of the methodology used. Key terms used in the study are outlined and explained. The research questions which drive the study are posed.
Chapter 2 – Literature review
Numerous studies are reviewed that investigate topics pertaining to this study. These include the theoretical assumptions of eye movements, eye movements in text and music reading, and sight-reading in music education.
Chapter 3 – Methodology
The methodology of this study is outlined clearly. The research design of this study is discussed, together with sampling and materials used in this study. The pilot study is also discussed, as well as ethical considerations.
Chapter 4 – Analysis
The results for this study are discussed. The group results for each sight-reading example are presented, together with statistical inference of the data.
Chapter 5 – Discussion
The research findings are discussed in detail. The findings are linked to existing studies, and conclusions are drawn from the data.
Chapter 6 – Conclusion
The study is evaluated critically in terms of its strengths and weaknesses. A brief conclusion is made based on the findings of this study and the research questions are answered. Suggestions for future research are also discussed.

The thesis concludes with a list of appendices

Chapter 2 – Literature review

2.1 Introduction

Chapter 2 introduces and discusses current theories which focus on text and music score sight-reading. It also presents a theoretical overview of the eye-tracking technology which is used to capture data in this field of research. First, a review of theories that address the eye movements occurring during text reading tasks is presented. Second, a theoretical review of the task of sight-reading a music score is provided, highlighting key differences between sight-reading a music score and text reading. Third, the theories regarding the development of sight-reading in music education are discussed. Finally, the functionality and efficacy of eye-tracking technology is discussed. A short summary concludes this chapter.

2.2 Theoretical understanding of eye movements in text and music reading sight-reading

Madell & Hébert (2008) claim that the scope of current empirical research exploring the eye movements that occur when sight-reading a music score does not compare to the far greater research output that investigates text reading. While numerous theoretical studies examining sight-reading and teaching strategies do exist (Leonard & House, 1959; Lowder, 1983; McPherson, 1994) and provide valuable theoretical insights into the art of sight-reading, empirical studies provide very focused, data-specific approaches to research questions. This type of data can be used in an effective manner to inform future theoretical studies.

Some empirical studies of eye movements in text reading (Balota et al., 1985; Rayner et al., 2006) that link ocular data with interactions between fine-grained structural properties of text have provided some insight into the cognitive processing involved in text reading. Although music and text reading do not necessarily utilise all eye movement parameters, constraints in the use of the oculomotor system require the use of similar basic mechanisms (Madell & Hébert, 2008). Most of the current knowledge of eye movements and cognition stems from the text reading domain. Thus, the body of research in this domain is the main source of information regarding eye movements and cognition in general.

2.2.1 Fixations and saccades

According to Puurtinen (2018a), reading (both text and music) is achieved by two basic eye movements. The first eye movement is referred to as a fixation and the second eye movement is referred to as a saccade. Fixations are short, stationary pauses of eye movements (roughly 200 – 300 ms), during which time the eye absorbs information (Holmqvist et al., 2015; Madell & Hébert, 2008; Puurtinen, 2018). Saccades are rapid shifts (4 – 50 ms) between fixations and are an instinctive cognitive method of suppressing (processing) information gained by fixations.

Initial eye movement research focused on establishing how much information can be absorbed by one fixation. McConkie and Rayner (1975) developed a phenomenon known as the ‘moving window’ technique, which established that readers were able to process word-length pattern information as far as fifteen character spaces ahead of fixation. Furthermore, word-shape and specific letter information could be processed as far as eleven character spaces ahead. This phenomenon of being able to process information ahead of fixation became known as the ‘perceptual span’. McConkie and Rayner (1975) suggest that the perceptual span is smaller for impaired or beginner readers. Madell and Hébert (2008, p. 158) expand on this concept by saying that the perceptual span is also described as a measure of “parafoveal information retrieval”; in other words, the ability to retrieve information beyond the point of fixation. Other research (Balota et al., 1985) links the cognitive processes involved in reading to the mechanisms of the oculomotor system. In their study, Balota et al. (1985) link fixation duration with both contextual constraints and parafoveal information. Interestingly, their research found that readers skip predictable words more easily than unpredictable ones. This finding has direct implications for reading music scores and will be discussed in more detail later in this chapter.

2.2.2 Cognitive processing during text and music reading

This section discusses the cognitive processes that occur during text reading and music reading. First, similarities between the two reading disciplines are discussed. Second, key differences between the two reading domains are highlighted.

2.2.2.1 Comparisons between text and music reading

Studies which explore cognitive processes when reading text and music yield somewhat contradictory results. Several studies investigate whether the cognitive processes when reading text and music are similar or comparable (Hébert & Cuddy, 2006; Roux et al., 2007; Sergent et al., 1992). For example, Hébert & Cuddy (2006) reviewed a number of studies which investigate parallel cognitive functions of professional musicians who had lost their ability to read music after incurring brain damage. In most of the studies reviewed, many of these individuals had also lost their ability to read text. This implies that the neural pathways activated when reading text and music are the same, or overlap.

Empirical research conducted by Roux et al. (2007) examines musicians undergoing surgery for brain lesions, using surgical data. The data were collected by direct cortical stimulation mapping. Their findings suggest that some cortical areas are common to both reading domains, while other areas can be distinct from each other. These findings seem to indicate that the cognitive processes involved in reading text and music are complex in nature. In research focusing on learning disorders, Hébert et al. (2008) studied a dyslexic musician learning to read music, using a specially developed music battery in their laboratory. This research suggests that there is an association between the two types of reading.

In contrast, numerous studies suggest that the neural pathways engaged in text and music reading differ. For example, a study by Sergent et al. (1992) used positron emission tomography as well as magnetic resonance imaging to study the functional neuroanatomy of their participants. Their research proposes that the neural networks for text and music reading are distinct and adjacent to each other.

Furthermore, in Hébert and Cuddy's (2006) review, some studies (Mavlov, 1980) interestingly showed that a few participants (when sustaining brain injuries) showed a loss of either text or music reading, which supports the notion of independence between these two abilities (Hébert & Cuddy, 2006). This finding contradicts the findings of studies like Roux et al. (2007).

A cognitive aspect of text reading was explored by Slattery et al. (2006) while studying ocular behaviour when reading short phrases like "an FBI" and "a FBI". Their results suggest that auditory imagery plays an important role in reading strategy, as it provides the reader with a temporal advantage (Slattery et al., 2006). If applied to a musical context, this finding has interesting implications regarding audiation (the ability to mentally hear a word/musical symbol before physically performing it) during sight-reading. Future research which explores whether audiation provides sight-readers with a temporal advantage may provide interesting correlations to this text-related finding.

In sum, studies examining the acts of text and music reading seems to posit contradictory results. Some studies argue that the cognitive processes involved in text and music reading are the same or similar, while others state that there are distinct differences. Future research could clarify this discrepancy.

2.2.2.2 Differences in text and music reading

Despite the alleged similarities or commonalities in cognitive processing between text reading and music reading discussed in the previous section, there are also several differences. This section outlines the main approaches to sight-reading (reading and performing a piece of music from a score not seen before) a music score and highlights key differences between music reading and text reading.

Arthur et al. (2016, p. 1) state that in order for music to be sight-read, the reader has to be able to "see it, contextualize it and then reproduce it on an instrument of choice". This aspect of sight-reading is quite unlike reading text. Although some studies explore the effect of fixation patterns during silent reading of music scores (Cara & Vera, 2016), silent reading is not the focus of this study. Sight-reading a music score implies the reading and performing aspect of the activity. Two of the standard international examining boards, Trinity College London and Associated Board of Royal Schools of Music, both allow students 30-second viewing time before a sight-reading performance is to commence (Trinity College London, 2017; ABRSM, 2019). A South African examination board, Unisa, states in their syllabus that sufficient time will be allowed to view sight-reading exercises before playing should commence (Unisa, 2016). Some of these examining boards allow students to play through sections of these exercises during this viewing time. While many studies disagree about viewing time (the time allowed between first viewing the score and starting the performance), the general concept of sight-reading is that it involves reading a score for the first time with little viewing time.

One of the first complexities readers encounter in sight-reading exercises, is the planning phase. Palmer and Van de Sande (1993) suggest that similarities do exist between the planning phases of music and text reading. Their research however posits that reading music scores requires some unique aspects of cognitive planning. The first distinct feature is the hierarchical processing properties of music symbols (Palmer & van de Sande, 1993). They argue that music notes are perceived as individual units first, and then grouped together to form two more hierarchical layers, namely chords (harmony) and keys (tonality). A further study suggests that structural content in music (phrase beginnings and endings) as well as the distance between elements within such a structure can influence planning (Palmer & van de Sande, 1995). This influence can be both positive (resulting in successful performances) or negative (resulting in unsuccessful performances). A study by Palmer and Pfordresher (2003) suggests that the planning phase in music reading is greatly influenced by performance memory. They argue that this memory retrieval system can in turn be influenced by aspects in the score like repeated elements and the presence of auditory non-verbal cues in phrase structures. Their study concludes that reading music involves a highly complex planning phase, which may in turn be influenced by several factors, resulting in either successful or unsuccessful performances.

Music notational symbols (known as notes by musicians) are more complex (Puurtinen, 2018a) than the symbols (letters of the alphabet) used in text reading. Puurtinen (2018a) argues that the notational symbols in any music score contain two different types of information, namely pitch and rhythm. Each symbol in a music score thus represents both pitch and rhythmic aspects, each implying different motoric processes to perform. 'Pitch' refers to the sound frequency of the note while 'rhythm' refers to the duration of the note and musical meter. Both these aspects must be identified and transferred to motoric actions to play the note correctly. A third category of symbols or information which needs to be interpreted, specifically important to keyboard players, is called 'harmony'. This refers to "groups of simultaneously performed notes or by chord symbols placed above the stave" (Puurtinen, 2018a). Performing these grouped symbols extend beyond just reading, rather requiring readers to group symbols and interpret them to form implied meanings which differ from single note symbols. This extension to the sight-reading process requires a theoretical and motoric understanding of the harmonic aspects of the score. In short, the complexity of the symbols used in sight-reading music scores differ greatly from the symbols used in text reading.

Drai-Zerbib et al. (2011) suggest that another challenge encountered in sight-reading is the motoric component of performance. They argue that sight-reading is not only a reading task, but a performing one too. In a similar vein, Saxon (2009) posits that the act of sight-reading has both input and output phases, arguing that every symbol in the score must be processed cognitively (input) before being transformed into a motoric action (output). The motoric output mentioned in this study refers to the performance aspect of sight-reading. Every musical instrument presents the reader with different motoric requirements. Clearly this motoric aspect adds an additional level of dimension to sight-reading music that is not present in silent text reading (which does not require motoric action).

In addition to the notational, temporal, and motoric aspects of sight-reading, musicians are also expected to interpret further requirements specific to their instruments when sight-reading scores. For example, some of the information needed by instrumentalists to execute these motoric components is not necessarily found in the score (Puurtinen, 2018a). This information includes fingerings, breathing marks and bowing marks. These motoric components are either determined before a performance or must be addressed when performing. The success of these motoric executions therefore relies to a large extent on the expertise of the musicians performing them. Similarly, Fourie (2004a) argues that in piano sight-reading, knowledge of the keyboard greatly improves sight-reading as it removes motoric barriers in the performance process. This supports the notion that technical expertise in the instrument used while sight-reading improves overall sight-reading ability.

Puurtinen (2018b) further claims that there are significant differences between the cognitive processes involved in silently reading scores (reading with no performance component) and sight-reading a score with the intent of performing it. She argues that no motoric planning occurs when silently reading through a score. She does, however, state that studying fixation patterns during silent reading tasks could be useful as a reference when comparing "music reading with the processing of other types of domain-specific symbol systems" (Puurtinen, 2018b, p. 150).

A further aspect of sight-reading a music score is the presence of a temporal component. Puurtinen (2018a) maintains that performing a piece of music imposes a temporal restriction on a performer. This means that every piece has a natural flow or pulse that should not be disturbed by stopping or pauses. Once a performer starts performing a music score, he or she must proceed without pausing until the end of the piece is reached. This temporal component is largely absent from silent language text reading domains. Kopiez & Lee (2006) further state that this temporal component also means that performers are unable to correct errors. This lack of opportunity to correct errors is absent when reading silently, as words can simply be re-read if errors occur.

While there are some commonalities in basic eye movements between text and music reading (Puurtinen, 2018), some specific eye movements involved in reading text and music seem to be different. Fourie (2004b) suggests that the eyes move forward in a horizontal direction during text reading. Sight-reading, especially piano sight-reading, involves horizontal, vertical, and diagonal eye movements. This suggests a more complex cognitive process for music reading than for text reading.

Interestingly, Fourie (2004a) says that reading and playing in isolation activate different areas of the brain. The specific areas of the brain involved in sight-reading are only activated when reading is combined with playing (Steward & Walsh, 2000). This finding submits that the act of sight-reading has unique implications on cognitive activity. This in turn suggests that attempting to isolate reading and performance is not a substitute for sight-reading, as they will activate different cognitive activities. Altenmüller (2001) furthermore posits that processing music occurs in both hemispheres of the brain. These findings propose that sight-reading is a complex cognitive task, involving several areas of the brain, areas that are uniquely activated when performing sight-reading tasks.

Thus, current theoretical assumptions seem to suggest that music sight-reading involves different cognitive processes to silent text reading due to the presence of temporal and motoric aspects, the intricacy of the notational symbols used and the lack of opportunity to correct errors. This study aims to provide some insight into the cognitive processes involved in reading key and time signature aspects in a music score. These findings could perhaps suggest educational strategies that could help develop sight-reading skills in students.

2.3 Eye movement research and music reading

This section provides an overview of the studies that attempt to link eye movements and music reading. First, a general overview of the studies will be discussed. Second, the eye-hand span phenomenon will be investigated. Third, the role of musical expertise on musicians' sight-reading abilities will be discussed.

Research which links eye movements and music reading dates back to 1928 (Jacobsen, 1928). This initial study concluded that a relationship exists between speed and accuracy in sight-reading. Weaver & Nuys (1943) photographed eye movements during piano sight-reading, drawing several conclusions. First, they conclude that one note is the musical equivalent of one word in language. Second, they found that the average reading pause is longer in music than in language. Third, they concluded that treble parts tend to be read first, and lastly that chords are not always read at one glance. These findings have mostly been disproved in the last century. The use of eye-tracking technology has greatly improved eye movement methodologies, providing more definitive answers to research questions. In 1952, Wheeler & Wheeler (1952) conducted a study that concluded that gender does not affect sight-reading ability. This finding still seems to be relevant to studies today, as it is still accepted that gender does not affect sight-reading ability.

The first major break-through in the research which links eye movements and cognition was made by Sloboda (1974; 1977a; 1977b; 1984), who argued strongly that music reading is directly linked to cognition and should be viewed as a form of music perception. A more recent study (Hayhoe & Ballard, 2005), examining eye movements in everyday activities, supports Sloboda's finding. The study suggests that "seeing is inextricably linked to cognitive goals" (Hayhoe & Ballard, 2005, p. 188) and furthermore found that humans need to be taught where to look in order to acquire the visual information they need. This suggests that, while visual patterns are linked to cognitive goals, the location of visual information is not automatically perceived. In everyday life, the visual locations needed to perform tasks are systematically acquired from a variety of sources such as mimicking the behaviour of others or specialised instruction. This supports Sloboda's theoretical finding regarding the link between cognition and eye movements.

In his early research, Sloboda (1974) studied the eye-hand span (the distance between performance and reading) by unpredictably turning off the lights during a sight-reading exercise. In this study, the eye-hand span was estimated by the number of notes the reader could perform after the lights were turned off. During the data collection proceedings, the lights were turned off at pre-determined points selected for their distance from clear phrase endings. This made it possible to evaluate the relationship between eye-hand span, phrase structure and sight-reading ability. He found that expert readers were able to extend their musical memories to the phrase endings. He proposed that phrase endings serve as a kind of musical mnemonic, which pulls the performer's memories to logical structural pauses.

A subsequent study by Sloboda (1977b) examines the cues that signal phrase endings in a music score more closely. He pays particular attention to the eye-hand span differences when boundaries are signalled by physical (long notes or rests) cues and structural (tonal-harmonic) cues. To test this theory, he presented participants with scores that were missing either physical or structural cues to test their effect on the eye-hand span. His conclusion indicates that structural boundaries increase sight-readers' eye-hand span, while physical boundaries present readers with a separation of chunks to be processed. This means that tonal and harmonic cues aid the increase of the eye-hand span, while space cues interrupt the forming of patterns. While Sloboda's work is technologically outdated, his findings provide a solid foundation for most of the future research linking eye movements and music reading. His work demonstrates an approach to eye movement research that focuses on highly specific aspects of the music score.

Some of the first studies to utilise eye-tracking in music score reading were conducted by Goolsby (1994a; 1994b). In his first study, Goolsby (1994a) examined the eye movements of twelve skilled and twelve poor sight-readers as they sang four single-line melodies. He focused his research on how the number of encounters with the score and complexity of the music score would be influenced by expertise. His results indicate no link between musical expertise and notational complexity or number of encounters (number of times the score was seen). He does, however, find that expertise influenced the length of fixations. The scores of less visual complexities elicited fewer and shorter progressive fixations (forward fixations), while more complex melodies produce shorter progressive saccade lengths (forward skips between fixations). Melodies containing long note values produce more and longer fixations. Another finding is that readers use more fixations during sight-reading (reading for the first time) than reading the same score for a second or third time (Goolsby, 1994a).

A second study by Goolsby (1994b) examines participants at the extreme ends of the sight-reading spectrum (a very unskilled and a very skilled reader) used in the first study. His aim was to investigate whether readers were differentially sensitive to the structural components of the score. Three of the four melodies used in the first study were used again in the second study. An important observation is that the skilled reader did not fixate on every note, but rather grouped or chunked several notes together. The unskilled reader did not exhibit this skill and struggled to simply keep the tempo. This strategy of note-by-note reading seems to be a common thread in numerous sight-reading studies that make use of amateur sight-readers. Goolsby's study was one of the first studies to theorise that expert sight-readers use patterns to perform sight-reading exercises. This finding is one of the core theories of this study.

Sloboda's (1974; 1977a; 1984) and Goolsby's (1994a; 1994b) research seem to suggest that musical expertise influences eye movements while reading musical notation. They also appear to suggest that eye movements and cognitive processes are inextricably linked. This in turn suggests that studying eye movements may give researchers valuable insight into the cognitive aspects of the music reading process (Madell & Hébert, 2008). Goolsby's (1994a; 1994b) research influenced several subsequent studies which explore aspects of musical sight-reading, most notably the eye-hand span, the effect of expertise on sight-reading, and the effect of complexity of sight-reading material on skills used. These three categories are each discussed in more depth in the following sections.

2.3.1 The eye-hand span

The eye-hand span refers to the distance between the point of reading and the point of performance in a sight-reading exercise (Madell & Hébert, 2008). Goolsby's research inspired numerous studies that focused on the 'eye-hand span' phenomenon as opposed to the perceptual span. In a sight-reading study, Furneaux & Land (1999) examine the effects of musical expertise and tempo on the eye-hand span. The research method uses a basic piano sight-reading task to gather data. The participants were divided into three categories; namely, experts, intermediate and amateurs. Two variables for the eye-hand span were calculated. These variables consisted of 1) a time index, which they defined as the length of time between fixating on a note and playing it and 2) the note index, which was defined as the number of notes between the performance position and the simultaneous eye position (Furneaux & Land, 1999). Their results indicate that musical expertise had no effect on the time index (the length of time between fixating on a note and playing it); however, the experts showed less variability in time index scores than intermediates or amateurs. Expert sight-readers also seemed to extract more information per fixation. Furneaux & Land (1999) conclude that the time between reading and note performance (the eye-hand span) was not affected by expertise, whereas information storage capacity was greatly affected by expertise.

A detailed study by Truitt et al. (1997) aimed to measure the eye-hand span and perceptual span of musicians performing sight-reading exercises. They used the “moving-window” technique by systematically adding chunks of notes at the end of a stave as readers were performing the tasks. They also utilised a metronome pulse to stabilise performances. They found that the musicians’ perception span of the score was roughly between two to four beats. They estimated the eye-hand span to be little over a crotchet, or one beat. Besides the eye-hand span and perceptual span findings, they also discovered that readers tend to fixate on blank spaces on the score. Only 49% of the notes were fixated on, with notes and blank spaces being fixated on with almost equal probability. Other aspects of the score that drew fixations were stems, bars, phrasing, and key signature. Similar results are reported by Gilman and Underwood (2003) and Kinsler and Carpenter (1995). Contrary to the findings of Furneaux & Land (1999), Gilman & Underwood (2003) and Truitt et al. (1997) find that expert sight-readers exhibit a bigger eye-hand span than amateurs. This finding suggests that expertise does have an effect on the eye-hand span.

A recent ground-breaking study by Huovinen et al. (2018) explores the effects of unexpected aspects in the score (such as intervallic skips) on the eye-hand span. They also expanded on the concept of eye-hand span by introducing the eye-time span. The eye-time span refers to the time difference between the metronome click (regulating a performance) and point of fixation. Their study explored 37 participants (pianists) reading and performing twelve five-bar diatonic melodies in C major. The melodies were composed in a stepwise fashion, with intervallic skips introduced at various places in each melody. This study theorised that the metronome click would automatically correlate with the point of performance (when a note is played), thus eliminating the performance aspect of the study. Most other studies had to use recordings of the actual performances to sync eye movements data and determine the eye-hand span. By using a metronome to monitor performances, the researchers theorise that they could calculate a more accurate point of performance, which is ultimately used to calculate the eye-time span. Their main concern with recordings as performance data collection is that there could be a time delay. The eye-time span aspect measured the ability of individual notes to catch a sight-reader’s eye during reading (Huovinen et al., 2018). The research posits that difficult notes elicit longer saccades than average notes. This means that a reader would react to a difficult note by directing a single, longer saccade towards it. For this reason, they also argue for the necessity of controlling tempo during reading exercises with the aid of a metronome. The study concludes that unexpected aspects in a music score (like intervallic skips) cause an increase in the eye-time span and the eye-hand span.

These studies present researchers with valuable insight regarding the eye-hand span. The research indicates that the eye-hand span is greater for expert readers than amateurs (Gilman & Underwood, 2003; Truitt et al., 1997). The perceptual span does not seem to be affected by expertise. This finding differs from the findings for text reading studies, where better readers seem to exhibit larger perceptual spans (Rayner, 1998). Another noteworthy finding proposes that unexpected aspects (intervallic skips) in a music score seem to increase the eye-hand span for expert sight-readers, drawing the reader's eye further forward in the score. These findings provide a useful theoretical foundation for this study.

2.3.2 The effect of expertise on sight-reading

Many studies focus on the differences between expert and amateur sight-readers, with the aim of discovering reading strategies applied by expert sight-readers (Arthur et al., 2016; Drai-Zerbib & Baccino, 2005; Goolsby, 1994a). These studies identify several specific kinds of skills honed by expert sight-readers. Kopiez & Lee (2008) argue that sight-reading expertise requires three main skills including pattern recognition of aspects in a music score, prediction skills and the ability to use inner hearing skills (audiation). In addition, Fourie (2004a) maintains that music scores constantly present readers with visual interference, which occurs when new visual information replaces already viewed information (for example when moving to a new fixation, new notes come into focus). She argues that experts can overcome these interferences by developing certain characteristics or skills. This section will discuss these characteristics in more detail.

2.3.2.1 Pattern recognition

Research shows that an important aspect of expertise in sight-reading is the sight-reader's ability to group information into patterns. Wolf (1976) contends that expert sight-readers use patterns to guide their reading process, claiming also that the ability to create patterns is directly associated with a sound structural knowledge of the music being read. Several researchers (Cara & Vera, 2016; Kinsler & Carpenter, 1995) further suggest that these structural aspects are hierarchically organised, suggesting that there is an order of importance utilised in sight-reading performance. For example, some sight-readers might place more value on the pitch aspect as opposed to the rhythm aspect. Penttinen and Huovinen (2011) concur, adding that bar lines could even aid this process, because they provide visual boundaries that help organise visual activity. Wolf (1976) furthermore proposes that notes that are beamed (like quavers) are chunked together and are processed in fewer fixations.

Polanka (1995) investigates the influence of pitch and musical structure on saccade lengths and fixation durations of musicians of different expertise. His study observes the eye movements of eighteen research participants silently reading and sight-singing melodies. These melodies aimed to vary the presence of primarily scalar or triadic patterns present in the score, as well as varying the length of these patterns. The scalar melodies were referred to as lower complexity and the triadic as higher complexity. While the results had to be interpreted with caution, they suggest that expert sight-readers can identify root-position triads as patterns. Polanka's (1995) findings thus proposes a correlation between expertise and pattern recognition.

Another aspect of sight-reading expertise; namely, tonal and visual complexity, was explored by Waters & Underwood (1998). The research focuses on the effect of tonal complexity versus visual complexity on the sight-reading ability of expert sight-readers and amateurs. The findings suggest that the expert sight-readers use fewer fixations to read tonally complex music than amateur sight-readers. They also found that visual complexities, such as missing bar lines, do not affect eye movements of amateur sight-readers. The study concludes that musical structure (patterns), rather than visual complexity (missing bar lines) has an impact on both eye movements and cognitive processes.

Arthur et al. (2016, p. 2) argue that an expert in any particular domain is "characterised by the ability to chunk aspects of that domain into smaller units for more efficient processing". This resonates with the notion (Cara & Vera, 2016; Kinsler & Carpenter, 1995) that the ability to chunk information is paired with a thorough knowledge of the domain. They also suggest that it is achieved by fewer and shorter fixations. By directing few and short fixations to a whole group of notes, expert sight-readers use fewer and shorter fixations than amateurs, who direct fixations to each individual note. Drai-Zerbib & Baccino (2005) report a similar finding by saying that expert sight-readers appear to have a better understanding of musical structures as well as a better knowledge of how to apply these.

2.3.2.2 Prediction skills

Another skill that expert sight-readers possess is the ability to detect errors in scores (Arthur et al., 2016). These errors refer to notes that are not part of the of the harmonic language that is presented in a score. Both Sloboda (1974) and Wolf (1976) argue that expert sight-readers are able to not only recognise these errors in scores, but will naturally correct them to conform to the harmonic language of the piece being played. Drai-Zerbib et al. (2011) support these findings, claiming that expert sight-readers use their musical knowledge to compensate for missing or incorrect information. This finding highlights the significance of being able to identify patterns in the reading strategies of expert sight-readers. This finding also serves as a key theoretical foundation for this study.

Similarly, Arthur et al. (2016) conducted an empirical study in which they expanded the error detection ability of sight-readers. They presented expert sight-readers with melodies that were missing key aspects of normal scores, such as bar lines and rests. The study proposes that removing key aspects of the music score seriously disrupts the fixation patterns of expert sight-readers. They argue that this means that an expert sight-reader's ability to recognise patterns is compromised by the disrupted aspects in the score as opposed to the tonal-harmonic errors discussed earlier. This in turn validates the existence of these patterns in the reading strategies of expert sight-readers. They also found that the missing aspects in the score had very little effect on amateurs, who simply adopted the note-by-note reading strategy. Fourie (2004a, p. 87) suggests that amateurs are "unable to activate the specific brain areas involved in the process as a whole", possibly resulting in this note-by-note reading strategy.

Another aspect investigated by Salis (1977) and Huovinen et al. (2018) is the effect of difficulty of sight-reading exercises on the eye-hand span of expert sight-readers. They posit that the eye-hand span of expert readers increases in relation to the complexities in the score. This suggests that expert sight-readers, rather than being negatively impacted by increasing complexity, are in fact able to identify complexities or aspects in the score that deviate from expected patterns. Their fixations are instinctively drawn forward in the music, increasing the eye-hand span. This finding will be explored in more depth in this study.

2.3.2.3 Audiation

A further phenomenon exhibited by expert sight-readers is the use of their inner ear, a sense of 'inner hearing' or audiation when reading musical material. Grutzmacher (1987) posits that expert sight-readers can find musical meaning by mentally hearing music read from a score. This suggests that audiation is a skill which any musician can develop. Gordon (2012) concurs, suggesting that through mastering the skill of audiation, a performer builds up a repertoire of essential and inessential tonal and rhythmic materials, which are all added to the performer's memory. Van Zyl (2018) agrees with Gordon's view that audiation is a good skill to have. However, he argues that the focus of these audiation skills should not be the development of sight-reading alone, but should serve the development of a number of other musical skills. Gordon says that audiation enables sight-readers to hear the piece (or aspects thereof) before sight-reading it, which must have enormous benefits when performing it. A further study done by Pascual-Leone (2001) suggests that if, during this audiation phase, a reader is able to mentally stimulate the motor acts required for a particular piece, some of the required neural structures are fired. This could explain why the motoric component of sight-reading exercises is more successfully accomplished by sight-reading experts. It is unclear, though, whether all musicians are able to develop this skill. Brodsky et al. (2008) theorise that only a third of musicians fully develop audiation, implying that further research is required to develop educational strategies that advance this skill.

Another attribute displayed by expert sight-readers, particularly during performance, is the level of proficiency on the instrument used to perform the sight-reading exercise. Fourie (2004a, p. 87) argues that (specifically in keyboard sight-reading), expert sight-readers “feel more comfortable about the topography of the keyboard when sight-reading and therefore seem to be less affected by interference during the process of visuo-motor translation”. This statement could be true for any instrument, as a high level of proficiency would prevent motoric interferences occurring during the sight-reading task.

This section highlighted key reading skills exhibited by expert sight-readers when performing an unknown work within a specific time frame. These skills are audiation, pattern recognition and grouping information together in the score. Expert sight-readers appear to be able to use these skills to effectively interpret the visual information in the score and transform it into motoric outputs.

2.3.3 The effect of music score complexity on sight-reading

Sight-reading exercises for examinations are graded according to levels of difficulty. This means that young musicians are expected to read exercises of increasing level of difficulty as they progress through higher grade levels. Very little research investigates the role the level of complexity (or difficulty) of the sight-reading exercise plays in a musician’s sight-reading ability. In other words, does more difficult sight-reading require more advanced skills, techniques, or expertise from expert sight-readers?

A study done by Kopiez & Lee (2006) explores this question. This study, unlike previous research, does not assume that expert sight-readers use all their skills for all levels of complexity of music they are reading. The research participants consisted exclusively of expert sight-readers. The participants were selected from a pool of graduate and post-graduate students. The researchers used a standardised sight-reading test (from the Unisa syllabus) as stimuli. The stimuli were organised into five levels of complexity, with five being the most complex sight-reading exercises. The researchers designed 32 variables, divided into three main categories. The first category focused on general cognitive skills, which included short-term memory capacity, working memory capacity, short-term music specific memory and general mental capacity. The second major category addressed elementary cognitive skills and included variables like speed of information processing, simple visual reaction time, simple auditory reaction time, tapping speed and trill speed. The final major category explored expertise related skills. The variables included in this category were accumulated hours of solo practice, accumulated hours of piano lessons and accumulated hours of sight-reading expertise.

The results propose that different variables gain or lose importance, depending on the complexity of the sight-reading exercise being performed. The study concludes that general cognitive skills are valuable only for the first three levels of complexity. Elementary cognitive skills are most active at level three of sight-reading exercises, while sight-reading expertise is most important at high levels of complexity. Interestingly, they concluded that audiation or inner hearing is also only useful at low levels of sight-reading complexity. This study makes the significant suggestion that different reading strategies are used at different levels of sight-reading complexity.

The researchers argue that sight-reading expertise can be viewed “as a combination of information processing, psychomotor speed and SR expertise” (Kopiez & Lee, 2006, p. 117). They also state that sight-reading demands on mental capacity, psychomotor skills and sight-reading expertise vary with the complexity levels of music being read. Interestingly, they assume that this adaptive behaviour of the sight-reader's brain reflects a basic feature of the human information processing, as the neurological system always chooses the optimum activation pattern for the respective task demands.

These findings imply that there is an identifiable link between complexities of sight-reading exercises and sight-reading performance skills. Since this study utilises sight-reading exercises of different levels of complexities, these findings provide an important theoretical framework to interpret results of future music reading studies. This study aims to expand on the concepts regarding complexities of sight-reading exercises and sight-reading skills.

2.4 Sight-reading in music education

The previous section discussed various skills which equip expert sight-readers to read musical scores fluently. It seems reasonable to surmise that these skills should be the focus of musical education and development in young pianists. For as Fourie (2004b, p. 16) argues, the "skills of piano sight-reading can be taught and learned" which intimates that these skills are not acquired automatically, but need be learned through instruction. Sight-reading therefore needs to form an integral part of music education in general. This section discusses the theoretical underpinnings of sight-reading in music education. A discussion of the practical implications of sight-reading in music education is also included, highlighting the challenges presented to teachers and students.

2.4.1 Theoretical underpinnings of sight-reading in music education

In 1983, Lowder (1983) conducted a survey to ascertain which skills are deemed important for college level pianists. This survey found that sight-reading was ranked the second most important skill, after identifying cadences. A similar survey was done by Kostka (1997), yielding similar results. This survey found that sight-reading skill was ranked second in order of importance, after musicality. The ability to sight-read is therefore deemed desirable and worth developing in young musicians. Thompson & Lehmann (2004), however, point out that sight-reading studies have so far focused almost exclusively on the Western tonal tradition. This is not viewed negatively, as "the classical tradition is more or less unique in identifying and prizing the skill at all" (Thompson & Lehmann, 2004, p. 144). This means that while sight-reading is primarily a Western tonal skill, the results can be generalised as they reflect the population of Western tonal musicians.

Several researchers have developed various approaches to sight-reading and its place in music education. In one such study, McPherson (1994) theorises that performing music consists of five sub-categories. These are performance of rehearsed music, sight-reading, playing from memory, playing by ear and improvisation. In a subsequent study, Kopiez & Lee (2006) suggest that these five categories overlap and that all of them can be improved with instruction. This strongly implies that training in any of these five categories can yield positive results. It also seems to suggest that improvement in any of these categories is linked to improvement in the others.

Fourie (2004b, p. 17) has a different view, however, arguing that for many years, sight-reading has been taught as a "by-product of performance study". She further states that the cognitive processes involved in rehearsed music and sight-reading are different. This suggests that while a connection does exist between the five categories of performed music, each aspect should receive sufficient attention in music education. This in turn implies that sight-reading should be taught as a skill on its own, with focus on the different processes of sight-reading to improve this aspect of musicianship. The fact that sight-reading does not seem to receive the same amount of instruction time could perhaps account for the lack of proficiency in sight-reading performance by pianists in general. This view is also expressed by McPherson (1994), who argues that sight-reading should receive more attention if this skill is to be improved. He posits that successful sight-reading occurs because of careful self-regulation. He subsequently proposes that students need to learn how to self-regulate their performances during sight-reading, as this ability is crucial to gaining mastery in sight-reading. His study further gives four categories that need to be self-regulated for a successful performance to be achieved. The first is the ability to seek important information in the score. This information includes key and time signatures as well as scanning the work to gain a sense of comprehension. The second category is a brief period of mental rehearsal. The third category is maintaining a good sense of concentration throughout the performance. The final category is self-monitoring. He stresses the importance of this final phase, as expert sight-readers seem to be able to use audio feedback to monitor their performance. McPherson's (1994) findings appear to emphasise the importance of self-regulation in sight-reading performances, suggesting that this aspect needs to be included in sight-reading teaching strategies.

In another approach, Leonard & House (1959) claim that developing skill in sight-reading requires developing awareness of tonal and rhythmic movements in the music, concepts of tonality, tendencies of chords and tones, the meaning of notational symbols, and the relationship between symbols and sounds that they represent. These findings suggest that sight-reading development relies on a plethora of sub-skills that are required to improve sight-reading skills. Petzold (1960) further adds to this list by saying that sight-reading is dependent on three perceptual levels. These are auditory perception of musical sounds, visual perception of musical symbols, and the way these two levels are internalised and organised to produce a piece of music from sight.

Taking another approach, Elliott (1982) investigates the relationship between sight-reading achievement and seven selected variables. The variables identified in his study were technical proficiency, sight-singing ability, rhythm reading ability, cumulative grade point average, cumulative theory grade point average, cumulative performance jury grade point average, and major instrument grade point average. The study finds that there was a strong relationship between sight-reading ability and rhythm reading skills. The study also concludes that rhythm-reading ability was the single best predictor of general sight-reading skills. This study strongly suggests that rhythmic ability forms a crucial part of sight-reading development, which in turn implies that rhythmic training is vitally important in sight-reading development.

In contrast to these findings, Grutzmacher (1987) says that for sight-reading to be developed, readers must develop a sense of tonality. This involves learning to use audiation (inner hearing) when listening to music as well as reading music scores. According to Grutzmacher (1987), this skill is developed successfully by vocalising. Mainwaring (1951) points out that from the early stages of music education, emphasis should be placed on the relationship of sound with musical symbol and action, rather than emphasising action with musical symbols alone. Thomas (1966) and Hoffner (1969) argue that, instead of focusing on these relationships, most instrumental teaching strategies favour showmanship and mechanical aspects of playing. Grutzmacher (1987) strongly suggests that audiation in the form of developing aural tonal skills should be employed when teaching sight-reading. Phillips (2013) concurs with this finding. These studies seem to suggest that a sense of tonality and audiation are vital parts of sight-reading development.

Killian (1991) expands on the tonal awareness concept by investigating the effect of error detection and perception training on sight-reading skills. He argues that using error detection and perception exercises as a pre-sight-reading training tool helps develop subsequent achievement. This error detection is in turn improved by aural perception exercises. This suggests that the error-detection skill possessed by expert sight-readers is one that can be developed and taught. This finding could be useful in creating educational strategies for sight-reading, as it provides valuable information regarding pattern recognition, which in turn helps with error detection.

In a more recent study, Liperote (2006) says that in both language and music development, four important vocabularies are listening, speaking, reading and writing. She argues that the most important of these four vocabularies is listening, since it forms the foundation on which the other three are built. Mishra (2014) agrees, listing ear-training as one of the key skills that can be improved with practice to facilitate sight-reading. Ear-training however can arguably consist of more sub-skills than just listening, since these concepts also need to be internalised. These findings support the importance of aural development when learning how to sight-read successfully.

Two successful schools of music education that firmly believe in the importance of the listening domain are those taught by Suzuki and Kodaly. In his book, Suzuki (1983) compares the process of learning music to that of learning a new language. He proposes that children hear the language first, before learning to speak it. Only once these two aspects are under control, do reading and writing commence. Suzuki's method embraces the idea that children who hear music as part of their natural upbringing become natural musicians. This in turn emphasises the listening aspect of music education as a pre-cursor to reading. Kodaly was another teacher who firmly believes in the value of the listening aspect of music education. In his method, Kodaly (Houlahan & Tacka, 2008) argues that hearing music is one of the key aspect in the development of musicality and specifically singing in young children. His method also advocates listening to music (especially native folk music) long before the notation symbols are taught.

A further approach to sight-reading instructions suggests that successful sight-reading seems to depend on the reader's knowledge of his/her instrument (Osborne et al., 1976). Fourie (2004a) argues that a sound knowledge of the keyboard (for pianists) removes interference in sight-reading. This happens because the motoric component of the sight-reading output phase does not interfere with the reading input phase. The sound knowledge of the keyboard could involve executing both the planning and performance actions involved in performing sight-reading exercises. Fourie's (2004a) finding applies to sight-reading on any instrument. This discovery also suggests a link between practical knowledge of an instrument and sight-reading ability. The research by Fourie (2004a) influenced this study, as it makes use of pianists as participants.

These findings seem to suggest that sight-reading development is a complex undertaking. The number of different approaches, each emphasising different skills, or sub-skills, indicates that sight-reading instruction requires a multifaceted approach.

2.4.2 Practical implications of sight-reading in music education

Various researchers and scholars have proposed practical approaches to develop sight-reading skills. Trantham (1970) argues that sight-reading skills can be improved by instruction, even in a group class setting. This suggests that the traditional one-on-one instruction is not the only method that can improve sight-reading skills. In the end, sight-reading is a practical act, requiring practical approaches to improve. This section discusses some of the practical approaches suggested by various studies.

Last (1972) argues that sight-reading should be included as part of a young pianist's development from the start of the learning process. She stresses the importance of including small reading exercises in every lesson. This could start with two bars and gradually increase in length. She also continues to suggest a step-by-step method, which includes learning to recognise intervals, memorising the notes on the lines and spaces of the stave, rhythmic exercises, and tied notes. Her method suggests that practical instruction should be done in a terraced method, only proceeding to the next step once a concept is grasped.

Phillips (2013) elaborates on this methodical teaching method by saying that students learn music in the same way that they learn language. She points to previous research, which finds that babies learn language in a predictable way, starting off with nonsense syllables, followed by simple words. Eventually simple sentences are constructed, leading to more complex ones. Finally, children learn to write these sentences. Phillips (2013) states that the implication of this process of learning language on learning how to read music is paramount. She says that music teachers should introduce students to pitches and rhythms aurally first, then allow them to reproduce them vocally, and finally expect them to read these combinations. Her findings suggest that this step-by-step method of instruction is paramount and should be designed with care to include all the skills required to sight-read well.

In another study, Osborne et al. (1976) stress that sight-reading must be taught in a fun way. They suggest six commandments that should be taught to students when they learn sight-reading skills. The first commandment is to develop the correct attitude towards sight-reading. The second is to develop the power of concentration, as they argue that sight-reading requires "total concentration" (Osborne et al., 1976, p. 65). The third commandment is to learn not to stop during sight-reading performances. The fifth commandment is to know your own instrument, while the sixth is to analyse the piece of music before playing it. These commandments summarise some of the major approaches to sight-reading used in music education for decades. They also provide valuable insight into sight-reading instruction for instrumental teachers.

In another approach, Hicks (1980) argues that sight-reading developments in its early stages should be introduced as an activity which develops problem solving. He argues that continuity and repetition should be emphasised. This idea is supported by Osborne et al. (1976). Hicks (1980) suggests that teachers should make use of materials that have repetitions, narrow pitch range, and include familiar aspects in each exercise. He also states that both rhythmic and melodic reading abilities and awareness should be developed. Phillips (2013) concurs with this statement. These findings provide valuable insights into the practical materials that can be used to develop sight-reading skills.

One of the methods employed by teachers in the past has been to use "shadowing" techniques, the covering up of certain parts of the score and moving the shadowing forward during the reading process. Kostka (2000) argues that this does not have any educational effect. In her study, using graduate students as participants, the test group who were exposed to this shadowing technique yielded the worst results of the entire test group. This suggests that the shadowing technique does not yield positive results when trying to develop sight-reading skills.

Speed (tempo) is another important variable (in addition to pitch and rhythm processing) in the sight-reading process. Several teachers may find that their students are unable to perform sight-reading exercises at a fast tempo. As a solution, Phillips (2013) suggests that sight-reading instruction should be done slowly (at least to start off with). She argues that slow tempi allow sight-readers to gain a better mastery of the skills required to sight-read efficiently. She also suggests that slowing down the tempo during sight-reading allows students to read ahead of the point of performance. This was previously described as the eye-hand span. This finding seems to indicate that the eye-hand span can also be developed with careful instruction. This study also seems to suggest that sight-reading at fast tempi are not possible without sufficient training at slower tempi, as important skills are developed at slower speeds.

Despite these findings and teaching methods, there are still numerous challenges facing students and teachers regarding sight-reading development. Carey (1959, p. 1) says that "as a group, high school students … [are] considered to be poor sight-readers". According to Elliott (1982, p. 6), this problem likely exists "due to a general lack of understanding of the sight-reading process itself". Hallam (2001) suggests that poor sight-reading occurs because amateurs tend to focus on one aspect of decoding notation at the expense of others. This could take the form of trying to focus on the pitches and neglecting the pulse, rhythm and so forth. McPherson (1994) claims that rhythmic errors far outweigh pitch errors during sight-reading tasks. Fourie (2004b) concurs with this finding.

Piano sight-reading in particular appears to present musicians with difficulty. Betts & Cassidy (2000) state that piano sight-reading requires reading multiple notes on two staves, frequently in different clefs. It also involves independence in both hands and often includes pedalling. This requires a different set of skills than those required for sight-reading single melodic lines. Fourie (2004b, p. 2) concurs by saying that one of the reasons musicians struggle with piano sight-reading is due to the "sheer complexity" of the sight-reading process. She argues that rehearsed music gives the brain an opportunity to recall stored memories. Sight-reading requires the pianist to perform without relying on these stored memory banks. Even if the musician is familiar with the symbols presented in the sight-reading exercise, it is presented in a completely new order and sequence. Fourie (2004b, p. 2) suggests that the brain has to "link similarities from memory maps compiled from both performance study and previous reading efforts in order to facilitate the sight-reading of a piece of music". This finding stresses the importance of developing all of the sub-skills required in sight-reading, as it seems that pianists have to rely heavily on these skills when performing sight-reading exercises.

Fourie's (2004) statement regarding the neglect of sight-reading instruction in favour of rehearsed music presents students and teachers with another challenge. If sight-reading and the skills this domain requires are frequently neglected, improvement in this domain is unlikely to occur. The current educational model seems ill-suited to aid students in developing sight-reading skills, as these skills remain notoriously under-developed in young musicians.

This section summarised some of the key findings of sight-reading research in music education. Numerous theoretical models for sight-reading development were discussed, as well as practical suggestions for sight-reading tuition. Despite these studies, sight-reading still seems to present teachers and students with significant challenges. This study will therefore aim to add to the body of knowledge regarding eye movements during sight-reading. These findings will in turn aim to provide teachers and students with information which can be used to develop strategies for effective sight-reading.

2.5 The use of eye-tracking technology in research

In the previous sections, several studies that examined eye movements and sight-reading were discussed. Many of these studies utilised eye-tracking equipment. This section briefly discusses the rationale for the use of eye-tracking equipment as a means of data collection for sight-reading studies, as it is also the means of data collection used for this study.

Eye-tracking technology has been used effectively in numerous studies to examine eye movements in both text and music score reading (Arthur et al., 2016; Cara & Vera, 2016; Drai-Zerbib et al., 2011; Goolsby, 1994a; Polanka, 1995). Eye-tracking was also successfully used to study reading texts (Rayner, 1998) as well as various other domains, like alternative communication (Jarodzka et al., 2017). Many researchers have validated the use of eye-tracking equipment in their studies. In one such review, Karatekin (2007) argues that eye-tracking can capture extensive information that our eyes relay. He also maintains that eye-tracking is non-invasive and can offer information about various cognitive processes. These include visual-spatial attention, object perception, memory, and language.

Puurtinen (2018b) furthermore claims that eye-tracking accurately records the durations and locations of fixations. She argues that reading music scores has one feature that makes it particularly suitable to eye-tracking technology. She says that:

> while reading, the performer produces a continuous motor response, as she is constantly ‘acting out’ the stimulus. This gives the researcher constant verification of the quality of the visual processing as well as the possibility of synchronizing, throughout a recording, the ‘intake’ of visual information with a motor output (Puurtinen, 2018b, pp. 149 - 150).

While not all studies require a recording aspect of the performance in order to perform data collection, the properties of eye-tracking technology highlighted in Puurtinen’s (2018) methodological review make the process suitable to use as a method of data collection for this study.

Unfortunately, eye-tracker studies in general seem to lack methodological consistencies. Madell & Hébert (2008) assert that collective results from eye-tracking studies can be quite confusing. This could be attributed to lack of statistical analysis as well as inconsistencies in methodologies. Puurtinen (2018a) notes that the first inconsistency in eye-tracking studies is the choice of music being read. Some studies present participants with sophisticated scores, while others use rudimentary exercises. She argues that experimental sight-reading exercises might be criticised for their simple nature, but they make it easier to see results for what is actually being tested (Puurtinen, 2018b). This notion could be the result of isolated aspects of the score being tested empirically.

A second inconsistency in eye-tracking studies appears to be the control (or lack of control) of tempo. Some studies do not control the temporal component of sight-reading tests, while others do. This makes comparisons of results very difficult. A further inconsistency is how studies determine expertise levels of participants. Puurtinen (2018) suggests that standardised pre-testing would help minimise this inconsistency. This method was successfully employed in some studies (Arthur et al., 2016; Kopiez & Lee, 2006).

In methodological reviews of eye-tracking studies, Madell & Hébert (2008), Puurtinen (2018a) and Fink (2019) call for studies with greater consistencies in methodologies. They collectively argue for the need to control tempo conditions in data collection. They also suggest that studies should move away from “coarse-grained properties to more carefully controlled fine-grained properties of the music on the page” (Madell & Hébert, 2008, p. 167). Puurtinen (2018a, p. 13) concurs, saying that future eye-tracking research should focus on the “basic elements of a music-reading task before embarking on more complex research designs where potential effects are blurred by other as yet unidentified factors”.

In music education, the need for eye-tracking studies is also crucial, as they could suggest powerful teaching strategies of sight-reading. Madell & Hébert (2008, p. 159) argue that:

> because the cognitive underpinnings of the reading processes are unknown, it is difficult to know the best teaching approach and to assess its efficacy in normal readers. In addition, it is almost impossible to find the locus of the problem in those who are experiencing substantial difficulties, and hence to suggest a remedial strategy as is being done for text reading.

They suggest that an understanding of the relationship between eye movements and structural and visual features on the page could help teachers better advise students while learning sight-reading.

2.6 Summary

This chapter outlined some of the important studies which explore eye movements during text and music sight-reading. The key differences and similarities between text and music reading were highlighted. Studies examining eye movements and music reading were also discussed in detail, highlighting key aspects like the eye-hand span and the effect of expertise on sight-reading ability. The research that focuses on sight-reading in music education was also reviewed, as well as studies which support the use of eye-tracking technology in music reading studies.

Empirical research focusing on sight-reading has so far explored general aspects of sight-reading. Several studies have focused on more specific cognitive processes during sight-reading (like the effect of errors on the eye-hand span). Very few studies have focused on the cognitive processes involved in processing specific aspects of music scores like key and time signatures. Key and time signatures are very specific aspects of music which provide clear information and require unique cognitive processing by sight-readers. This study aims to explore the cognitive processes which occur when readers process these two aspects of music. This exploration will be done by observing eye movements during sight-reading performances, as this method has proven reliable in previous research. Since it is theorised that expert sight-readers use patterns to read effectively, and that deviations from these patterns affect fixation patterns (Arthur et al., 2016), this study will make use of accidentals and time signature changes (serving as deviations) to explore this theory in more detail.

Chapter 3 – Methodology

3.1 Introduction

This chapter presents the research paradigm and methodology used in this empirical study First the researcher presents his choice of methodology and discusses the implications of a quantitative research design. This is followed by a detailed presentation of the processes of data collection, sampling, instrumentation, and procedures. The pilot study is outlined in terms of its aims, results, and recommendations for the main study. Ethical procedures are explained and reliability as well as validity of the research is discussed.

3.2 Research design

This study aims to explore the fixation patterns of expert and amateur sight-readers on two specific aspects of musical notation, namely key and time signatures. These two aspects were selected because they signify two major concepts in Western tonal scores, namely tonality and metre. Quantitative research designs aim to describe phenomena and emphasize objectivity in measurements (McMillan & Schumacher, 2010). These types of designs achieve objectivity by using numbers, statistics, structure, and control of conditions. Therefore, a quantitative research design seemed appropriate for this study's research design.

Quantitative research designs can be further sub-categorised as experimental, quasi-experimental and non-experimental. In experimental designs, researchers intervene with a procedure that determines what the subjects will experience (McMillan & Schumacher, 2010). Quasi-experimental designs are adaptations of experimental designs, except random sampling is not used. In non-experimental designs, researchers study phenomena or examine relationships between phenomena without directly manipulating conditions that are experienced by subjects (O'Dwyer & Bernauer, 2014). Simple descriptive quasi-experimental designs merely describe relationships or phenomena, while comparative research designs aim to examine differences between two or more groups.

This study uses a quasi-experimental quantitative research design. This research design was purposefully selected to objectively examine relationships between sight-reading ability and two variables (fixation count and fixation duration). Both variables are numerical data sets. A comparative design was utilised in order to compare expert and amateur sight-readers in this study, since these designs are specifically used to study relationships between different phenomena (McMillan & Schumacher, 2010). Quantitative research designs make use of variables to study phenomena. A dependent variable is the aspect of the study that is affected by the intervention, while an independent variable refers to the intervention or what was done by the researcher to influence the dependent variable (Babbie, 2008). This design is particularly useful when examining whether the dependent variable is different in two groups of participants. The comparison is thus made based on descriptive data.

Not all the conditions of the independent variable in comparative studies can be directly manipulated by the researcher (McMillan & Schumacher, 2010). Since the researcher could not directly manipulate all of the independent variables in this study, the quasi-experimental comparative research design was selected. The conditions that could be manipulated by the researcher included the sight-reading tests themselves as well as the inclusion of various key and time signatures as well as deviations. This research design enabled the researcher to compare the results for fixation patterns for both participant groups (expert and amateur sight-readers). The independent variables in this study were identified as the sight-reading examples (which is further subcategorized into key and time signatures as well as deviations) used by the researcher to examine the sight-reading, as well as the nature of the two groups (expert and amateur sight-readers). The dependent variables were identified as the fixation patterns (fixation count and fixation duration) and sight-reading performances of the participants.

Various measures were put in place to ensure reliability and objectivity in this study. Validity in quantitative research refers to the degree to which explanations of phenomena in a study match reality (Thyer, 2010). It also refers to the truthfulness of the conclusions and findings of a study. Objectivity can refer to both a procedure and a characteristic. As a characteristic, objectivity refers to research being unbiased and not subjective. As a procedure, objectivity refers to data collection and analysis procedures from which a single reasonable interpretation can be made. Together, these terms describe the quality of data produced and procedures that either control for bias or take into account subjectivity (McMillan & Schumacher, 2010).

This study aims to examine the fixation patterns of expert and amateur sight-readers. Since a comparison needs to be made between the patterns of two different groups, the comparative quantitative research design was the ideal choice. The research design allowed the researcher to compare different variables within fixation patterns of each group to come to logical conclusions. Since the researcher could only manipulate some of the conditions during data collection, the quasi-experimental design was a suitable choice for this study.

3.3 Participants

Participants for this study were recruited by means of convenience sampling. Convenience sampling is used to create a sample based on the accessibility of the participants, practical constraints and efficiency (McMillan & Schumacher, 2010). According to Gravetter & Forzano (2011, p. 151), this type of sampling selects participants "on the basis of their availability and willingness to respond". This type of sampling can be considered weak because it may not represent the entire population represented in a study. However, a researcher can compensate for this weakness by selecting a varied sample that comprises participants of various ages, genders, and performance abilities. In this study, participants were selected to meet these criteria. Further weaknesses of this type of sampling include the possibility of bias and reduced external validity (McMillan & Schumacher, 2010). The researcher used standardised sight-reading tests with a standardised mark rubric to avoid bias. Reduced external validity was minimised by interpreting results in terms of the population represented by the sample, rather than over-generalising results.

3.3.1 Participant selection criteria

A sample size of eighteen participants participated in this research study. Each participant was screened according to specific criteria, as outlined in **Table 2**. The theoretical justification for these criteria is outlined in **Table 2**, as well as the measure used to ascertain whether participants met these criteria.

Table 2: Criteria, justification and measures used to select participants.

Criterion	Justification	Measure Used
Group A (Expert sight-readers)		
Age: Participants required to be over the age of 18.	Fulfillment of Rhodes University Ethical Clearance.	Biographical questionnaire.
Gender: Both male and female participants were used in this study.	Studies show no correlation between gender and sight-reading expertise.	Biographical questionnaire.
Piano proficiency: Participants required to be able to play the piano (as first or second instrument)	All sight-reading exercises were composed for piano.	Biographical questionnaire

Participants required to possess a practical qualification of a minimum Grade 6 level from any recognised standardized examining body.	Participants needed to possess a certain level of proficiency to be compared to each other.	Interview upon entering the data collection venue. Standardised sight-reading test presented upon entering data collection venue.
Experience: Participants were asked how many years they had been playing the piano. This criterion was eventually discarded [1]	This information could prove useful when interpreting data; however, it was not necessary to exclude participants.	Biographical questionnaire.
Group B (Amateur sight-readers)		
Age: Participants required to be over the age of 18.	Fulfillment of Rhodes University Ethical Clearance.	Biographical questionnaire.
Gender: Both male and female participants were used in the study.	Studies show no correlation between gender and sight-reading expertise.	Biographical questionnaire.
Piano proficiency: Participants required to be able to play the piano (first or second instrument).	All sight-reading exercises were composed for the piano.	Biographical questionnaire.
Participants required to possess a practical qualification of a minimum Grade 6 level from any recognised standardised examining body.	Participants needed to possess a certain level of proficiency to be compared to each other.	Interview upon entering the data collection venue. Standardised sight-reading test presented upon entering data collection venue.
Experience: Participants were asked how many years they had been playing the piano. This criterion was eventually discarded.	This information could prove useful when interpreting data; however, it was not necessary to exclude participants from the study.	Biographical questionnaire.

3.3.2 Recruitment of participants

The participants for this study were recruited via email from Port Elizabeth and Makhanda (Grahamstown). The participants consisted of piano teachers from Port Elizabeth and Makhanda, as well as piano students from Rhodes University and Nelson Mandela University.

The researcher contacted the piano teachers directly via email. They were each sent an invitation to participate in the research process (**Appendix A**). In order to contact the piano students, the researcher first contacted the piano lecturers at both Rhodes University and Nelson Mandela University. They were asked to inform their students of the study and communicate the researcher's request for student participation. Once consent was given, the researcher contacted them via email to invite them to participate in the study. Some of these participants were known to the researcher. The researcher requested that the respective piano lecturers ask their students for contact details if consent was given to participate in the research study.

Once consent was given, participants were sent a biographical questionnaire (**Appendix B**) via email to complete. This took the form of a Google Form, which each participant completed and submitted to the researcher online. Each participant was also emailed an informed consent letter (**Appendix C**), detailing the ethics surrounding the study, as well as explaining

[1] The criterion regarding expertise was eventually abandoned since sight-reading skills and expertise in a particular instrument cannot be directly linked. For example, a musician could have experience as a violinist, for instance, and less experience as a pianist. The skills required to sight-read successfully could therefore have been developed while playing the violin. Keyboard expertise can therefore not be a true reflection of the participant's sight-reading ability, although it may have an effect.

the research process. Each participant signed the letter of informed consent prior to participating in the data collection process.

Once participants returned the biographical questionnaire, the researcher contacted them via email, detailing dates and venues for data collection to take place. This was accompanied by a Google Sheet, giving participants the opportunity to book a time in which to come for data collection.

3.3.3 Assignment into two groups

All participants undertook a standardised sight-reading test upon arrival for data collection. The results of this standardised test enabled the researcher to assign each participant into one of two groups during analysis. Group A (expert sight-readers) consisted of piano teachers from Port Elizabeth and Makhanda, as well as piano students from Rhodes University and Nelson Mandela University who achieved high scores on the standardised test. Group B (amateur sight-readers) consisted of piano teachers from Port Elizabeth and Makhanda, as well as piano students from Rhodes University and Nelson Mandela University who achieved low results on the standardised test.

The researcher used a standardised method to assign participants into each group. Each participant was required to perform a standardised Grade 6 sight-reading example (**Appendix D**), selected from the Trinity College London syllabus (2011, p. 16). The example used was Number Four in the Grade 6 syllabus. The selection criteria used in this study were also used in a study by Arthur et al. (2016). This example was assessed using the Trinity College London sight-reading rubric. Participants who scored 80% or higher were assigned to Group A (expert), while those who scored below 80% were assigned to Group B (amateur).

Each participant's performance was recorded with a video camera and assessed using the rubric published in the Trinity College of Music's exam procedures. According to the rubric, in order to achieve 80% or above in a sight-reading test, a candidate needs to display "a good sense of fluency though with occasional inconsistencies in control of pulse, rhythm and tonality" and "a good degree of accuracy in notes despite some slips, with some musical detail realised" (2017, pp. 36 - 37).

The standardised test was used because these tests are already validated by an examination panel. It gave the researcher the ability to differentiate between expert and amateur sight-readers and draw a sample for comparison.

The researcher initially aimed to use two groups of equal size (each group consisting of ten participants). However, practical constraints made this impossible. Many participants returned the biographical questionnaires and indicated their availability to participate in the study, but were unavailable for data collection for various reasons. Of the 35 participants who initially consented to take part in the study, only 23 came for data collection (65% response rate).

After the data were collected, five participants had to be excluded from the study for the following reasons:

- Two participants could not perform the sight-reading examples under the required metronome conditions. They subsequently spent more time performing each example than the other participants. Since fixation duration was one of the variables in this study, they had to be excluded.
- One participant frequently looked around the data collection room while performing the examples. This seriously affected his fixation patterns and made his results unusable.
- One participant moved her head up and down during performances, trying to keep time. The Tobii manual details that at least one eye must be on the screen at all times in order

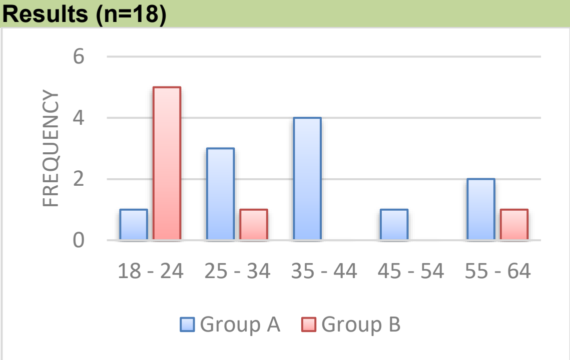
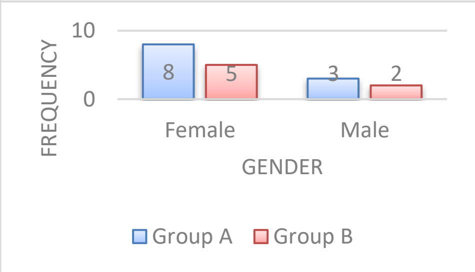
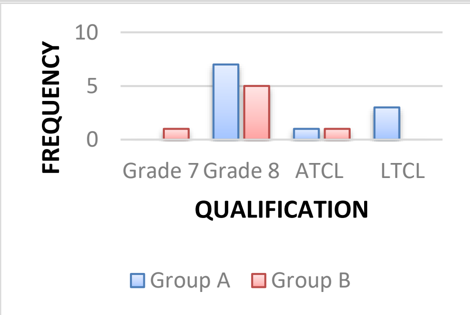
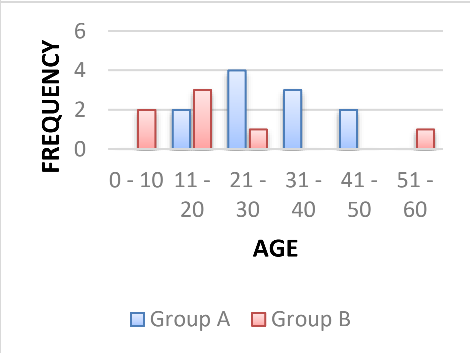
for the eye-tracker to register a fixation (Tobii, 2010b). This participant's head movements meant that this was not the case, and many of her fixations were not registered, rendering her data unusable.

- One participant was unable to adhere to the four metronome count viewing time before performing each example. This affected her fixation patterns, making them incomparable with the other participants.

3.3.4 Description of participants

This study compared two groups of participants, namely expert and amateur sight-readers. Group A (expert) consisted of expert sight-readers and Group B (amateur) consisted of amateur sight-readers. Each participant was assigned a number to protect his/her identity. **Table 3** outlines the details of participants according to age, gender, proficiency, and experience.

Table 3: Participant details

<table>
<tr><th>Description</th><th>Results (n=18)</th></tr>
<tr><td>Age:
The mean age for Group A (expert) was 38, while the mean age for Group B (amateur) was 28.</td><td>
</td></tr>
<tr><td>Gender:
Most of the participants were female (73%), while a further 26% were male. Group A (expert) consisted of 3 male participants and 8 female participants. Group B (amateur) consisted of 2 male participants and 5 female participants.</td><td>
</td></tr>
<tr><td>Proficiency:
Most participants possessed a Grade 8 qualification (66.6%). A further 5% held a Grade 7, 11% had an ATCL and 16% held a LTCL qualification. Group A (expert) consisted of seven participants with Grade 8, one with an ATCL and three with a LTCL qualification. Group B (amateur) consisted of one participant with Grade 7, five with Grade 8 and one with an ATCL qualification.</td><td>
</td></tr>
<tr><td>Experience:
Group A (expert) consisted of 18% participants with less than 20 years of experience, 63% participants with 20 to 40 years of experience, and a further 18% participants with 50 to 70 years of experience. Group B (amateur) consisted of 71% participants with less than 20 years of experience, 14% with 20 to 40 years of experience and 14% with 40 to 60 years of experience.</td><td>
</td></tr>
</table>

Of the participants outlined in **Table 3**, 94% indicated that the piano was their first instrument, while 6% indicated that it was their second instrument. This criterion was not deemed necessary to exclude participants from this study. It was, however, included in the biographical questionnaire, as the results could be used to interpret and derive meaning from the data.

3.4 Instrumentation

The researcher utilised specialised equipment and materials in the research project. These included the sight-reading tests, eye-tracking equipment and various other forms of collecting data such as the electronic keyboard, Tobii Studio Software, and a metronome. This section discusses the data collection tools in detail.

3.4.1 Tobii specialist

Given the specialised method of data collection using an eye-tracker, the researcher employed a skilled Tobii specialist to operate the eye-tracker equipment and software, and to guide this part of the data collection procedures. Ms Emmerentia Emmerich acted as the Tobii specialist for this study. She holds Bachelor's degree in Occupational Therapy and a Master's degree in Augmentative and Alternative Communication from the University of Pretoria. She currently works for Inclusive Solutions, where her duties include assessment, prescription, and training assistive technology. She is also the company's Tobii research eye-tracker advisor and technical support, as well as the Tobii Studio technical support. She is one of a handful of people in South Africa with Tobii experience and was therefore essential to the data collection process.

3.4.2 Consent forms

Participants were sent an invitation to participate in the study via email (**Appendix A**), requesting a written response indicating their willingness to participate in the study. Once this response was received, participants were sent an informed consent form, which outlined the research process and explained their rights as a participant in this study (**Appendix C**). This was signed by the participants and presented upon entering the data collection venue.

3.4.3 Biographical questionnaire

A biographical questionnaire (**Appendix B**) was developed for this study to create participants portfolios and sent to the participants with the informed consent form. This information was used to determine participants' general eligibility for this study. **Table 4** presents the questions used in the biographical questionnaire according to aspect of enquiry, type of question and reason for inclusion.

Table 4: Details of biographical questionnaire

Aspect	Type of Question	Reason for inclusion
First name	Open-ended question	To link the information on the biographical questionnaire to the participant's responses on the Tobii Studio Software.
Surname	Open-ended question	To link the information on the biographical questionnaire to the participant's responses on the Tobii Studio Software.

Age	Open-ended question	To ensure that participants met the age criteria of the study.
Is the piano your first instrument?	Yes/no question	To establish the level of competency of participants.
How many years have you been playing the piano?	Open-ended question	To establish the level of experience of participants.
Do you consider yourself to be a good sight-reader?	Yes/no/maybe question	To establish the participant's view of his/her competency and set up a preliminary group list.

3.4.4 Standardised sight-reading test

Participants were asked to state the highest level of graded piano practical qualification they had achieved. This was to establish the level of proficiency and ensure that they met the minimum Grade 6 requirement to participate in the study. This question was asked verbally when participants were first contacted, then the information was recorded upon the participant's arrival for data collection. This information was subsequently added to each participant's profile.

The researcher utilised a standardised sight-reading test (**Appendix D**) for this study. The purpose of this test was to assign participants into the two groups. The sight-reading test was taken from the Trinity College London's Grade 6 sight-reading syllabus. It was composed in C minor and in 6/8 time. The rationale behind the use of a standardised sight-reading exercise as a method of group assignment was that the exercise had already been graded by an expert panel. According to the Trinity College London's piano syllabus, Grade 6 sight-reading requires a candidate to be familiar with keys up to three sharps or flats with their respective minor keys (Trinity College London, 2017). If one considers the fact that the sight-reading examples can modulate to the dominant of any key, that means that keys up to four sharps are required. Time signatures of 2/4, 3/4, 4/4 and 6/8 are required. The sight-reading examples composed for this study, although simpler in terms of melodic content, are only slightly more complex in terms of key signatures (they include examples in five sharps and five flats). The standardised example was therefore a useful tool to establish a level of proficiency amongst participants. A similar approach was used in a study by Arthur et al. (2016).

3.4.5 Sight-reading examples

The researcher composed two sets of sight-reading tests that were assigned to every participant. Test 1 consisted of nine sight-reading examples (an additional three examples were analysed separately) while Test 2 consisted of four sight-reading examples (with an additional example analysed separately). Test 1 was administered before Test 2. The examples in Test 1 were presented in a random order. The same procedure was followed for Test 2. This means that there was no pre-decided order in which the sight-reading examples would be presented to participants. This was done to prevent any one example influencing how participants reacted to the next. The researcher also wished to avoid any detectable pattern emerging in the order of sight-reading examples.

3.4.5.1 Test 1

The researcher composed twelve melodies for Test 1. The purpose of these melodies was to identify and observe the effect of key and time signatures on fixation patterns.

The researcher initially intended to rank and present the melodies to participants in order of difficulty. However, on reflection, this idea was abandoned, as ranking the examples in order of difficulty would mean that expert sight-readers may detect a pattern and alter their responses. If a pattern like increasing order of difficulty were detected by some participants, they may have increased their level of concentration throughout the test, thereby altering the natural responses to the examples. The researcher subsequently decided to present all examples to participants in random order. This means that each participant saw the examples in a different order. Since each participant was presented with several examples, it was important that a response to one example should not influence the response to another example. McMillan & Schumacher (2010, p. 185) argue that when subjects are presented with several measurement instruments, the "order of their administration should not be the same for all subjects". They emphasize the notion that any specific example should not have a discernible effect on any other example.

A second original plan that was abandoned was to compose melodies containing key signatures up to and including examples in six or seven flats or sharps. Since all participants had to perform the examples in the same amount of time, the notion of six or seven flats or sharps was likely to be too challenging for amateur sight-readers, and therefore impractical for the purposes of this research. Sight-reading examples were therefore composed up to and including five sharps or flats. The examples were also limited to major keys, since minor keys could introduce accidentals that are not seen as deviations from expected tonal patterns.

All sight-reading examples in Test 1 were composed to be performed by the right hand only. The hand position for each example was a flexible one, requiring participant to switch between hand positions. This technique could be criticised for being too simple; however, previous studies done by Puurtinen et al. (2018b) have used similar methods, claiming that "in the end, one can argue with more certainty what one's findings might mean and what their cause might be" (Puurtinen, 2018b, p. 158). The rhythmic values used in these examples were limited to crotchets, minims, dotted minims, and semibreves. **Table 5** outlines the characteristics of the sight-reading exercises for Test 1.

Table 5: Test 1 Sight-reading examples

Example	Key signature	Time signature	Deviations	
			Accidentals	**Change of Time signature**
1	C major	4/4	0	0
2	G major	4/4	1	0
3	B-flat major	3/4	0	2
4	A major	2/4	2	0
5	D major	4/4	0	4
6	D-flat major	3/4	2	0
7	E-flat major	5/4	0	1
8	E major	4/4	2	0
9	F major	2/4	0	4
10	A-flat major	4/4	3	2
11	G major	4/4	0	0
12	F major	2/4	0	0

All examples outlined in **Table 5** can be viewed as **Appendices E1 – 12**. A variety of keys and time signatures were used, and many examples also included deviations. Two types of deviations were included, namely accidentals and changes of time signature. For example, if a piece is composed in C major, it generally only contains notes that are found in the C major scale. These are C, D, E, F, G, A, B, C. A note like F# does not belong to C major, so if F# does appear in a piece composed in C major, it is referred to as an accidental. Some examples also included changes of time signature. For instance, an example composed in 4/4 time could change to 2/4 time. The reason for including these was that they would investigate the patterns used by expert sight-readers when reading music, which in turn could affect the fixation patterns.

One example (Example 1) contained no deviations and was composed in C major. Two further examples (Examples 11 and 12), composed in F major and G major, also contained no deviations. These examples were initially included because the researcher theorized that they would be useful as a base-line score. Huovinen et al. (2018) explain the significance of a baseline score in a study which explored the effect of intervallic skips on the 'eye-hand span'. Puurtinen (2018b, p. 155) included several melodies without intervallic skips, stating that the research team "needed these stepwise melodies so that we could have a baseline with which to compare the melodies with larger skips". During the analysis of this study, it became apparent however that these melodies did not provide the base-line score they were designed for. They did however yield some interesting results of their own, which are reviewed in the Discussion chapter. For this reason, the examples were analysed separately from the rest of Test 1. Test 1 therefore consisted of nine sight-reading examples (Examples 2 – 10).

In this research, a metronome mark of 60 crotchets per minute for each example was maintained to provide consistent conditions for data capturing. Tempo is an important variable in the research, as it has direct implications for the participant responses to the research stimuli. This was observed in a previous study by Huovinen et al. (2018), who studied the effect of deviations like intervallic skips to expected patterns in sight-reading exercises on fixation patterns. As Puurtinen (2018a, p. 7) argues, if readers are allowed to read music naturally (without the temporal aspect being controlled in the experiment), some readers might simply choose a slower tempo than others, which would affect fixation patterns. Thus, controlling the tempo with the use of a metronome ensures that every participant reads and responds to the stimulus under the same temporal conditions. This is an important means of validating the data collection conditions. It also ensures that fixation durations can be empirically compared in analysis, as each participant is allowed the same amount of time looking at the screen.

3.4.5.2 Test 2

A second test was included in the data collection process. This consisted of five sight-reading examples composed for both hands. The rationale behind Test 2 was the intention to study the effect of key and time signatures and deviations on fixation patterns in music more closely resembling music that would be played by musicians on a daily basis.

The examples were presented to participants in a random order. Participants were required to perform these examples with a metronome mark of 60 crotchet beats per minute. The rhythmic values used in these examples were more complex than those used in Test 1. The key signatures were varied to include keys up to and including five flats or sharps. Only major keys were used. Time signatures were limited to 4/4, 3/4, 2/4, 5/4, 6/4 and 3/2.

Table 6 outlines the characteristics of the sight-reading examples composed for Test 2 in terms of key signature, time signature and nature of deviations. All examples can be viewed as **Appendices E13 – 17**.

Table 6: Test 2 sight-reading examples

Example	Key signature	Time signature	Deviations	
			Accidentals	Change of time signature
13	B-flat major	4/4	2	0
14	E major	3/2	5	0
15	B major	3/4	0	2
16	D-flat major	5/4	1	3
17	C major	4/4	0	0

Most of the examples depicted in **Table 6** included deviations like those used in Test 1. The rationale was to investigate the effect of accidentals and changes of times signatures on gaze patterns. One example (Example 17) was composed in C major and was initially included to provide a base-line score. The analysis process revealed that this example did not in fact provide a base-line score, thus it was analysed separately. Test 2 therefore consisted of only four examples (Examples 13 – 16).

3.4.5.3 Validation procedures for Test 1 and 2 sight-reading examples

The sight-reading melodies for Test 1 and 2 were sent to three experts for validation. McMillan & Schumacher (2010) recommend this course of action as a means of ensuring measurement validity. These experts were selected because they are lecturers in piano at different universities in South Africa and have expertise in sight-reading. The experts consulted were Dr Erika Bothma from Nelson Mandela University, Dr Tinus Botha from North West University and Dr Ben Schoeman from the University of Pretoria. The experts were each contacted via email. They were sent a PDF version of all the sight-reading examples as well as the Google Form Questionnaire. The questions and results are outlined in **Table 7**.

Table 7: Expert questionnaire

Question	Type of Question	Rationale	Response
In your opinion, would the examples in Test 1 be playable by all participants?	Yes/no question	Establish a suitable level of difficulty for examples. Also ensure maximum performance response from participants.	100% of experts said yes.
Do these examples provide participants with a variety of key signatures?	Yes/no question	Establish efficacy of key signature aspect in examples.	100% of experts said yes.
Do these examples provide participants with a variety of time signatures?	Yes/no question	Establish efficacy of time signature aspect in examples.	100% of experts said yes.
If these examples are presented to participants in a random order, is there a predictable pattern that emerges?	Yes/no question	Establish random nature of examples and prevent pattern emergence.	100% of experts said no.
If you selected yes, please explain what pattern you detect.	Open-ended question	Determine nature of pattern so adjustments could be made.	No response to this question.

All three experts agreed that the examples would be playable by participants and that the key and time signatures were sufficiently varied. They also agreed that there would be no detectable pattern if these were presented to participants in a random order.

3.4.5.4 Display settings

All sight-reading examples from Test 1 and 2 as well as the standardised sight-reading test from the Trinity College London syllabus were presented to participants in the form of a slide show. The examples were composed in Sibelius Software and exported to PDF format. The stave size was 10 mm. The researcher initially used a stave size of 7 mm, which is the standard stave size in Sibelius. Once the examples were exported, however, this small stave size caused a blurring effect, rendering the examples unreadable to participants. Examples were initially exported in portrait orientation. This proved problematic, as examples did not display in full screen mode once inserted into the slide show. The orientation was subsequently changed to landscape, which meant that examples were displayed in full screen mode in the slide show. All examples were displayed with a white background.

The initial layout of the musical examples appeared as two lines of musical notes, each line consisting of four bars. This layout proved problematic when displayed in the slide show, as the notes were displayed too close to each other, which complicated fixation patterns. The layout for examples in Test 1 was subsequently adjusted to comprise three lines. Line one consisted of three bars, line two of three bars, and line three of two bars. Examples in Test 2 (consisting of both right and left hand), however, were presented in two lines.

All examples were emailed to the Tobii specialist, who then imported them into a slide show using the Tobii Studio Software. The slide show consisted of two separate tests. Test 1 consisted of twelve examples, each preceded by a rest slide. The rest slide took the form of a white background and a single red dot in the centre near the top of the slide. Participants were instructed to look at the dot when a rest slide appeared. This ensured a uniform starting gaze point for every musical example. The musical examples were set to appear in a random order for every participant. The slide show started with the standardised sight-reading example, followed by an instruction slide. The examples of Test 1 then followed the instructions slide. A separate slide show was created for Test 2. This consisted of five examples, each preceded by a rest slide. An instruction slide preceded all the examples. The examples were set to appear in a random order.

3.4.6 Operating the Tobii Pro X2-60 Hz eye-tracker and Tobii Studio Software

Eye-tracking hardware and software have been successfully used in sight-reading studies (Huovinen, et al., 2018; Puurtinen, 2018a). This study utilised Tobii Pro X2-60 Hz eye-tracker to measure the variables of interest. The Tobii Pro X2-60 eye-tracker uses

> … infrared diodes to generate reflection patterns on the corneas of the subject's eyes. These reflection patterns, together with other visual data about the subject, are collected by image sensors. Sophisticated image processing algorithms identify relevant features, including the eyes and the corneal reflection patterns. Complex mathematics is used to calculate the 3D position of each eyeball, and finally the gaze point on the screen (Tobii, 2010a).

This means that the eye-tracker can build a three-dimensional model of any person's eye and record its movements on a screen.

The Tobii Pro X2-60 eye-tracker used in this study has a sampling rate of 60 point-of-gaze recordings every second. This means that it can obtain a point-of-gaze sample every 16.6 milliseconds (Tobii, 2010b). The sampling rate ensures a high level of accuracy, making the eye-tracker a reliable data collection instrument.

The hardware was supported by Tobii Studio Software and Microsoft Excel. The Tobii studio software was used to set up the slide show and to set up an individual profile for every participant. Each participant's performances for both Test 1 and 2 were recorded using the Tobii Studio Software. The software was also used to analyse and visualise the data collected from performances. The results were exported to Microsoft Excel to summarise and make statistical calculations.

The slide show was shown to participants on a Samsung 19" LCD monitor mounted on a height-adjustable floor stand, connected to a laptop computer. The initial strategy was to use only the laptop to project the musical examples to participants. This proved problematic, because the laptop computer screen could tilt. This meant that two variables had to be considered before collecting data, namely the angle of the screen as well as the height. The mounted computer monitor was subsequently preferred because it eliminated the tilting variable from the preparation phase. The only variable that could be adjusted before data collection was the height of the screen to accommodate seating heights of participants.

Data were exported using several formats, namely heat maps and gaze plots:

3.4.6.1 Heat map

A heat map is a data depiction output that occurs when using the Tobii Studio Software. It is a visual representation of the location and duration of all fixations. It can be viewed by a participant or as a group. The duration of fixations is indicated using colour. Green dots are very quick fixations. The colour gradually changes to red as fixation duration increases, thus correlating with fixation duration. **Figure 1** presents a generic example of a heat map that was randomly selected from this study for illustration purposes.

Figure 1: Heat map

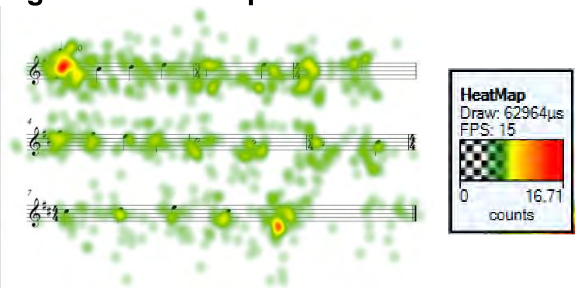


Figure 1: Heat map

3.4.6.2 Gaze plots

The Tobii Studio Software can export recorded data in another form, called gaze plots. A gaze plot shows the location of each fixation in the order that they occur in the recording. Each fixation is numbered on the gaze plot, depicting the order of fixations. **Figure 2** is a randomly selected gaze plot image from this study.

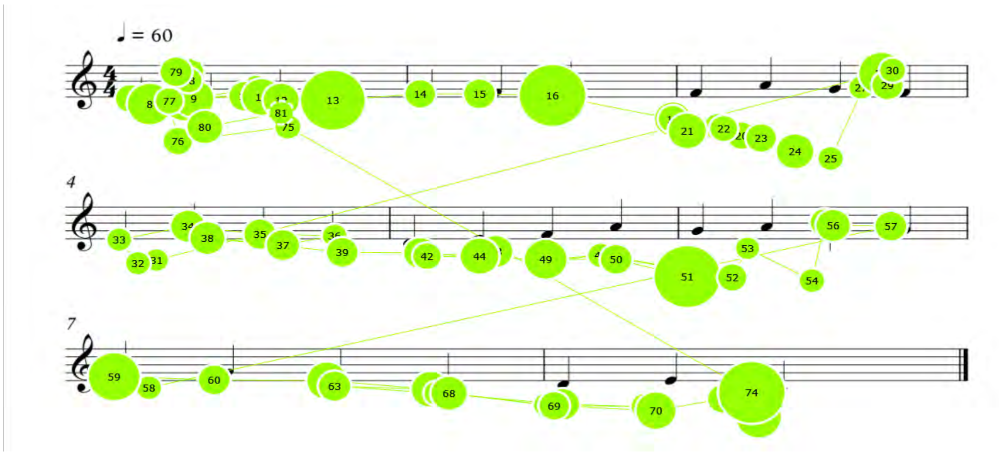


Figure 2: Gaze plot image

3.4.7 Keyboard and metronome

All sight-reading examples were performed on a standard, full-size digital piano keyboard. Participants performed all examples seated on a piano stool. The height of the piano stool could be adjusted to allow for different seating heights of participants.

A standard metronome was used in this study. This was set to 60 crotchet beats per minute, or one beat per second. The metronome was operated by the researcher for the duration of the data collection procedure.

3.4.8 Samsung video camera and tripod

All data collection sessions were video recorded with the participants' express consent. The video camera was mounted on a tripod. The video recordings were used for procedural purposes as well as in the analysis of the data. In order to protect the identity of each participant, the camera was angled away from the participant's face. This was done to adhere to the ethical procedures of the Rhodes University Ethics Committee. Ethical procedures state that researchers are not allowed to disclose personal details of participants in the research process (American Psychological Association, 2013).

3.4.9 Procedural reliability

A procedural checklist (**Appendix F**) was set up to ensure that the same procedure was followed for every participant. An independent observer reviewed 30% of the video footage of the data collection sessions and confirmed that the checklist was followed. Procedural reliability was calculated by dividing the number of correctly followed steps by the total number of steps in the procedure. This was then multiplied by 100 in order to calculate a percentage of correctly followed steps. The percentage for this study was 93%.

3.4.10 Review questionnaire

A review questionnaire was sent to participants after data collection occurred. The purpose of this questionnaire was to ascertain the participants' experiences during the data collection. The aim was to retrieve qualitative data that would potentially aid the analysis phase of the study. The questions are depicted in **Table 8**, as well as the rationale and the type of question used. Since the questions were almost all open ended, the answers will be discussed later in the study.

Table 8: Review questionnaire

Question	Type of question	Rationale
How stressful did you find the data collection process?	Open-ended question	To establish the stress level of participants during data collection, since this could affect performance ability.
Could you please write a sentence or two describing what made you feel uneasy or stressed during data collection?	Open-ended question	To ascertain what reasons contributed to the presence of stress.
How did you feel reading music on a screen instead of a page?	Open-ended question	To establish whether the screen affected sight-reading ability.
How did the metronome affect your ability to sight-read?	Open-ended question	To establish the effect of the metronome on sight-reading performance
How did you feel about the presence of the researcher and the Tobii expert in the data collection room?	Open-ended question	To ascertain whether the presence of the researcher and Tobii specialist had any effect on sight-reading ability.
Did the video camera affect your ability to sight-read?	Open-ended question	To establish whether the presence of the video camera affected sight-reading performances.
Are there any last comments or suggestions?	Open-ended question	To collect information regarding the efficacy of the methodology used in this study

3.5 Procedures

3.5.1 Data collection

All data collection was done using a Tobii Pro X2-60 Hz eye-tracker. This technology recorded the fixations of participants in all the sight-reading examples. The data analysis was performed using Tobii Studio Software and Microsoft Excel. This method of data collection has low inference, making it an objective and consistent method of data collection (Tobii, 2010c). To ensure procedural reliability, all data collection sessions were video recorded (with participants' consent).

Prior to data collection, the data collection equipment was set up in a quiet room. The Tobii Studio Software allows for the identification of areas of interest (AOI). These areas are used for specific data extraction and analysis. The key and time signatures of each example was isolated and labelled AOI A. All deviations were identified as AOI B. Two further notes (G and T) from each example were isolated and labelled AOI C. G was the first note of bar three in Test 1 and the first note of bar five in Test 2. These notes were isolated to use as a control aspect. The researcher and Tobii specialist programmed all details of participants (age, sex, proficiency level and experience) in the Tobii Studio Software.

For the eye-tracker to build this 3D model of the participants' eyes, a calibration process was performed by every participant. This took the form of a nine-point process, which calibrated the stimulus presentation display and the infrared sampling camera. The calibration process took the form of a red dot that moved through nine points across the screen. Participants were instructed to fixate on the moving dot. Their fixations were recorded at each of these static points. The Tobii Studio software indicated whether the calibration results were acceptable or not. Green results indicated high accuracy, yellow indicated intermediate accuracy and red for poor accuracy. The calibration process was repeated when low accuracy was produced until the results were accurate.

3.5.1.1 Instructions to participants

Upon arrival at the data collection venue, participants were invited to sit on the piano stool and indicate whether the stool height was acceptable to them. The height was adjusted for those who indicated the need for it. The height of the screen was also adjusted to accommodate each participant's seating height. Each participant was then asked for their consent regarding the video recording of the data collection process. They were also given the informed consent form (**Appendix C**) to read and sign if they agreed to the terms set out in the document. The document was witnessed by the Tobii specialist, who was present for all data collection sessions.

The participants were introduced to Ms Emmerentia Emmerich, the Tobii equipment expert. She operated the Tobii equipment in all the data collection processes and assisted in exporting the data from the Tobii Studio Software. Her role in the data collection process was explained to participants prior to data collection. Participants were informed that the first step in the process would be to perform the calibration process required by the Tobii Studio Software. The calibration process was performed until accurate results were achieved. Some participants were required to repeat the calibration process if inaccurate results were achieved. Some participants questioned whether wearing glasses would affect results. The Tobii specialist informed them that glasses do not affect the accuracy of the eye-tracker. The exception is bifocal glasses, as these bend light, resulting in inaccurate fixation readings. The Tobii specialist also explained to the participants how the eye-tracker functions.

Once an accurate calibration was achieved, the researcher explained the next steps of the data collection process to the participants. Participants were informed that the data collection process would continue as a slide show. The Tobii expert operated the slide show from the laptop computer. The layout of the slide show was explained to participants. Participants were instructed that they could perform the initial standardised sight-reading exercise at their own speed. They could also take as much preparation time before their performance as they wished.

For the examples used in the data collection process, a metronome mark of 60 beats per minute was utilised. The researcher explained to participants that once a slide appeared, they would have four metronome counts (indicated verbally by the researcher) to read it before commencing with their performance. The slide would disappear (removed by the Tobii specialist) as soon as the final bar was completed (there would be no extra viewing time). Each example was preceded by a rest slide, which remained on the screen for four metronome beats only. Participants were instructed to focus on the red dot on each rest slide. Once a participant confirmed understanding of these instructions, Test 1 commenced without stopping.

Upon completion of Test 1, participants were informed that Test 2 would follow immediately. The test was preceded by the same calibration process used in Test 1. This process was repeated until accurate results were achieved.

Participants were told that Test 2 consisted of five examples, which should be played with both hands. Each example would be preceded by a rest slide of similar nature to the ones used in Test 1. The same metronome conditions would apply to these examples as the ones utilised in Test 1. The metronome was once again operated by the researcher, who also counted out the beats in a similar fashion to Test 1. The Tobii specialist operated the laptop computer, controlling the slide show. The slide show started with an instruction page, outlining the data collection procedures. Participants were given an opportunity to ask questions. The slide show ended with a black slide indicating the end of the data collection process. Upon indicating understanding of these instructions, Test 2 was conducted.

3.5.2 Data analysis

Prior to commencing the data analysis, dependent variables had to be defined. The Tobii X2-60 Hz eye-tracker has a sampling rate of 60 point-of-gaze recordings per second. This means that it can record a point-of-gaze every 16.6 ms (Tobii, 2010a).

The Tobii X2-60 Hz eye-tracker was programmed to collect data pertaining to the following categories 1) Performance accuracies, 2) Average fixations on scores as a whole 3) AOI A (fixations on key and time signature aspects), 4) AOI B (fixations on deviations) and 5) AOI C (fixations on two randomly selected notes). The two notes used in AOI C were 1) T (a tonic note from each example) and G (the first note of bar 5 in Test 1 and the first note of bar 3 in Test 2). AOI A, B and C each contained two variables; namely, fixation count (number of fixations) and fixation duration (duration of fixations in seconds). Once all of the data was acquired, the results for AOI A, B and C were calculated as percentages of total score fixations. This allowed the researcher to accurately compare fixation percentages on the various aspects of the music scores.

The data collected was summarised by means of descriptive statistics. These aimed to transform the numbers into descriptors and characteristics of the data (McMillan & Schumacher, 2010). The small sample size meant that data could be presented on graphs depicting group scores per sight-reading example. This method of frequency distribution allowed for the description of individual scores, as well as calculating the mean scores in each group (McMillan & Schumacher, 2010).

The Tobii Studio Software allows for the identification of AOI. These were predefined as the key and time signature at the start of each example. The dimensions of these AOI can be seen in **Figure 3**.

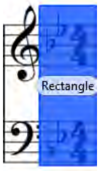


Figure 3: Dimensions of AOI

Further AOI included the key signature (if applicable) at the start of the second and third lines of each example (the key signatures for both these lines were selected as one AOI). Any accidentals or changes of time signatures (both referred to as deviations in this study) were also selected as AOI. All sight-reading examples with AOI marked can be found in **Appendix G1 – 17**.

The dimensions of an AOI on an accidental and change of time signature can be seen in **Figure 4** and **5**.

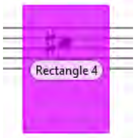


Figure 4: AOI on accidental

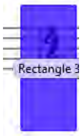


Figure 5: AOI on change of time signature

The number of AOI in each example depended on the number of deviations included in it. **Table 9** outlines the number of AOI in each musical example.

Table 9: Number of AOI in examples

Example	Number of AOI
1	3
2	5
3	6
4	6
5	8
6	6
7	5
8	6
9	8
10	9
11	4
12	4
13	6
14	9
15	7
16	8
17	3

These AOI were used to select data appropriate to this study. Fixation count and fixation duration were calculated for each participant in these AOI. Three categories of AOI data were selected for this study. AOI A included all key and time signature aspects, while AOI B included all deviation aspects. Two further aspects of each score were selected for analysis and labelled AOI C. These two aspects comprised of one tonic note for each example, as well as a note in the same geographic location on the score for each example (the first note of bar 5 for Test 1 and the first note of bar 3 in Test 2). This area of interest was only added after the pilot study was completed, as the results did not make much sense without the use of this control aspect as a comparison. All examples were assessed, and accuracy recorded. The accuracy of deviations was compared to the accuracy of total scores.

Each example was assessed in order to calculate performance accuracy and performance errors. This formed a fourth data category. The Trinity College London sight-reading rubric could not be used as an assessment tool in this study, as the examples did not contain any dynamic markings, articulation, or expression details. The researcher therefore calculated the total number of notes (including rests) for each example. Each participant's performance was assessed, and their total incorrect notes (pitch and rhythm) were recorded for each example. In order for a note to be marked as correct, both the pitch and rhythm element had to be correct. The total errors were added together for Group A (expert) and divided by the number of participants in the group to indicate the average number of errors for each example. The same procedure was followed for Group B (amateur).

The number of possible deviations was also recorded for each example, as well as each participants' number of errors on deviations. This was done so that the total errors for each example can be compared to the total errors on deviations. Accidentals were marked incorrect if not performed correctly, while a change of time signature was marked incorrect if the participant did not adjust the metre in the bar containing the change of time signature. Performances which did not adhere to the four-beat metronome viewing time were removed from the analysis, as they would present incomparable fixation patterns. Only the performances with uniform starting and ending times were used in analysis.

This study uses descriptive statistical techniques to interpret data. The techniques used were mean and frequency count. Statistical inference was applied to the data in order to ascertain whether the difference between the two groups' scores were significant. An expert in statistics was employed to calculate statistical differences between the two groups.

3.6 Pilot study

After the data collection procedures, selection criteria and measuring equipment were selected, a pilot study was conducted with one participant. After the pilot study, recommendations were made for the main data collection process.

3.6.1 Aims of the pilot study

The aims of the pilot study were to test the selection criteria, the measuring equipment, and the proposed procedures for the study.

3.6.2 Participant

The participant who completed the pilot study met all the criteria for this study. The participant was 50 years old with piano as her main instrument. She had played piano for 41 years and held a piano qualification of Grade 7 from a recognised examining body.

Table 10 outlines the aims, materials, procedures, results, and recommendations to the main study of the pilot study.

Table 10: Aims, materials, procedures, results, and recommendations of pilot study.

Aim	Materials	Procedures	Results	Recommendations for main study
A: **Selection process**				
1. To determine whether the biographical form completed by participant yielded sufficient information to determine whether she met all criteria.	Biographical form sent via Google Forms.	Questionnaire was sent to participant via Google Forms. It took some time to get responses.	The questionnaires provided information about criteria required for the main study.	The questionnaire failed to ask the practical qualification of each participant. A note was made, and each participant was questioned about this information upon entering the data collection room.
B: Testing the measuring equipment				
2. To test the efficacy of the computer setup and ensure optimal function of the eye-tracker.	Laptop computer, computer monitor, height-adjustable floor stand, Tobii X2-60 eye-tracker.	The eye-tracker was set up in a room at right angles to any window or light source, fluorescent lighting was avoided and switched off when necessary.	The eye-tracker and setup worked well and did not negatively impact the collection of results.	The setup described was replicated in data collection of main study.
3. To determine the efficacy of the calibration process.	Tobii X2-60 eye-tracker and Tobii Studio software.	The nine-point calibration process was conducted with the participant.	The calibration process worked well and was completed at the first attempt.	Should the initial calibration process fail, the height of the eye-tracker and screen should be adjusted, and the calibration process repeated.
4. To ensure that the musical examples slide show would display properly in the Tobii Studio Software.	Tobii Studio Software, 17 musical examples, 1 screen test.	The slide show was set up with alternating rest slides to ensure a uniform starting gaze point.	The slide show displayed in full screen.	Settings should remain identical for the main study.
5. To ensure the video camera records clearly and adheres to ethical standards.	Video camera and tripod.	Video camera was set up to record participant avoiding an angle that would record her face.	The recording was clear and adhered to ethical standards.	Keep video camera settings and position for main study.
C: To evaluate testing procedures				
6. To evaluate whether procedural protocol ensured procedural reliability.	Video recording, procedural protocol sheet.	Independent viewer viewed the footage and commented on the efficacy of protocol during data collection.	Instructions were communicated and protocol sheet was followed. The participant could not count the four beats of the red dot and the four beats preceding performance	Protocol sheet adapted to say that the researcher would assist by counting four beats for each red dot slide, and four beats

			herself. The researcher had to start counting those beats out loud for the participant.	before starting each performance.
D: To evaluate data analysis procedures.				
7. To evaluate whether the results from Tobii Studio Software measured the desired variables.	Tobii Studio Software, Microsoft Excel.			
a) The mean total fixation count for each example (Test 1 and 2 separated) on AOI A (key and time signature).	Tobii Studio Software, Microsoft Excel.	Selected media to be included in analysis. Selected participant to be included in analysis. Selected metric – total fixation. Recorded fixation count data on AOI A in each example.	Scores were obtained and could be plotted on a graph.	The same procedure should be repeated in the main study. Group scores would have to be calculated for the main study. The total group score for each example would have to be divided by the number of participants in each group to obtain a usable average group score per example.
b) The mean total fixation count for each example (Test 1 and 2 separated) on AOI B.	Tobii Studio Software, Microsoft Excel.	Selected media to be included in analysis. Selected participant to be included in analysis. Selected metric – total fixation. Recorded fixation duration data on AOI A in each example.	Scores were obtained and could be plotted on a graph.	The same procedure should be applied to the main study. Group scores would have to be calculated for the main study. The total group score for each example would have to be divided by the number of participants in each group to obtain a usable average group score per example.
c) The mean fixation duration for each example (Test 1 and 2 separated) on AOI A.	Tobii Studio Software	Selected media to be included in analysis. Selected participant to be included in analysis. Selected metric – fixation duration. Recorded fixation duration on AOI B in each example.	Scores were obtained and could be plotted on a graph.	The same procedure should be used in the main study. Group scores would have to be calculated for the main study. The total group score for each example would have to be divided by the number of participants in each group to obtain a usable average group score per example.
d) The mean fixation duration		Selected media to be included in analysis.	Scores were obtained and could be plotted on a graph.	The same procedure should

for each example (Test 1 and 2 separated) on AOI B.		Selected participant to be included in analysis. Selected metric – fixation duration. Recorded fixation duration for AOI B in each example		be applied to the main study. Group scores would have to be calculated for the main study. The total group score for each example would have to be divided by the number of participants in each group to obtain a usable average group score per example.

The pilot study results indicated that the initial biographical questionnaire was insufficient to gather all the information needed for participation in this research project. The researcher had to question participants regarding their highest practical qualification once they entered the data collection venue and recorded this information. Combining the information from the biographical questionnaire and the interview regarding practical qualifications provided enough information to qualify participants for the study. The data collection protocol had to be modified to assist participants counting the four beats for each red dot slide and the four beats preceding each performance. The data collection methods were effective and reliable, and the necessary information could be extracted from the Tobii Studio Software to be used in the data analysis. However, the variables chosen for the data analysis did not yield results which could effectively be compared, because participants did not use the same number and duration of fixations for entire scores. After careful review, it was decided that two variables, namely performance accuracy and total score fixations, should be added as data variables. Also, an additional area of interest, AOI C consisting of two rule-based notes (AOI C) were added to the data analysis as a control aspect. The results for AOI A, B and C were calculated as percentages of total screen fixations, in order to more accurately compare results and formulate clear conclusions.

3.6.3 Pilot study results

Since there were no groups in the pilot study for the comparisons to be made with the results, the aim was to ascertain whether the necessary data could be extracted from the Tobii Studio Software. The results pertaining to fixation counts (**Figures 6** and **7**) and fixation durations (**Figures 8** and **9**) are summarised as follows:

Total Fixation Count on AOI A and AOI B in Examples 1 – 12

The total fixation count on AOI A (key and time signature) and AOI B (includes all deviations) for Examples 1 to 12. **Figure 6** details the results.

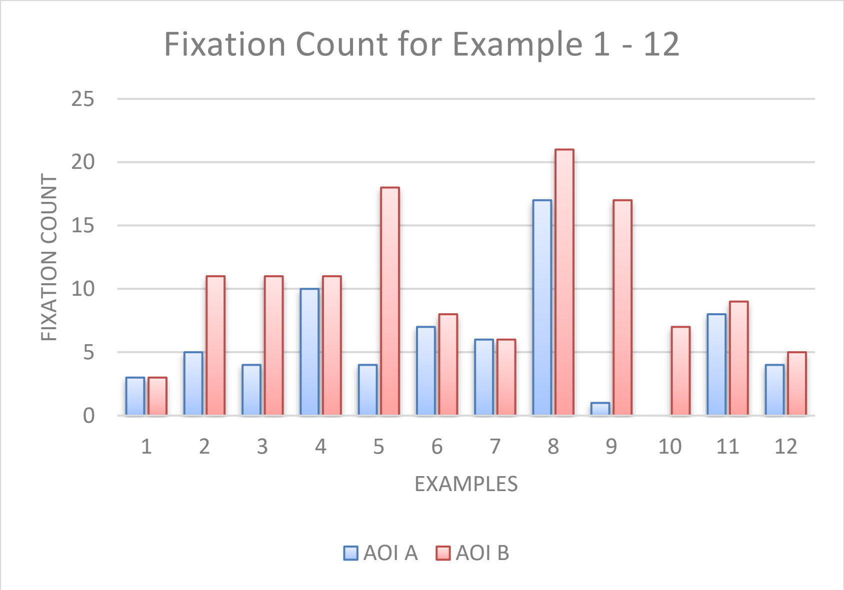


Figure 6: Fixation count for AOI and AOI B in Examples 1 - 12

The participant's total fixation count on AOI A across all examples was 69, with an average of 5.75 per example. The total fixation count on AOI B was 127, with an average of 10.58 per example.

<u>Total Fixation Count on AOI A and AOI B in Example 13 – 17</u>

The total fixation count for AOI A (key and time signature) and AOI B (includes deviations) for Examples 13 – 17. **Figure 7** shows the results.

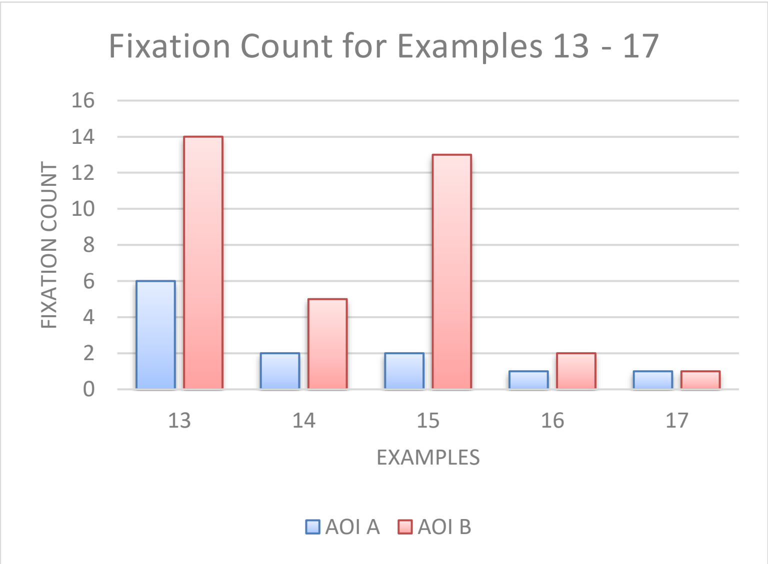


Figure 7: Fixation count on AOI and AOI B for Examples 13 - 17

The participant's total fixation count for AOI A across all examples was 35, with an average of 7 per example. The total fixation count on AOI B across all examples was 35, with an average of 7 per example.

<u>Total Fixation Duration on AOI A and AOI B in Examples 1 – 12</u>

The total fixation duration for participant on AOI A (key and time signature) and AOI B (includes all deviations) for Examples 1 to 12. The results can be seen in **Figure 8**.

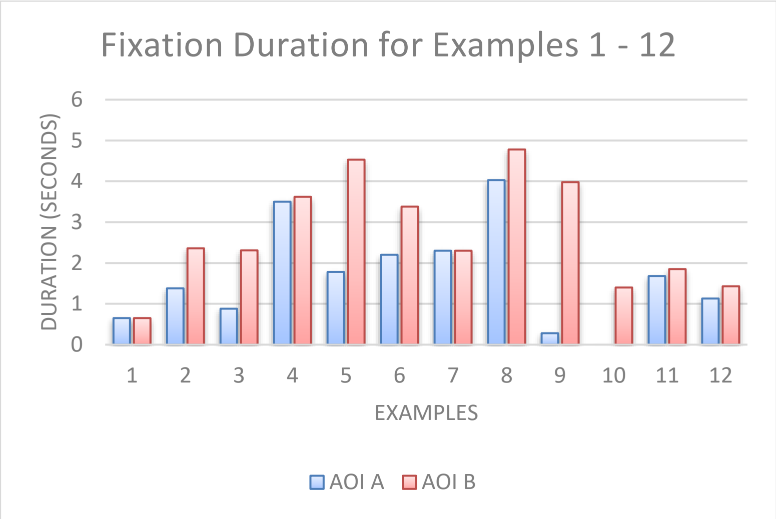


Figure 8: Fixation duration on AOI A and AOI B in Examples 1 - 12

The participant's total fixation duration on AOI A for all examples was 19.81 seconds, with an average fixation duration of 1.65 per example. The total fixation duration for AOI B was 32.59, with an average of 2.72 per example.

<u>Total Fixation Duration on AOI A and AOI B in Examples 13 – 17</u>

The total fixation duration for participant on AOI A (key and time signature) and AOI B (includes deviations) for Examples 13 to 17. **Figure 9** details the results.

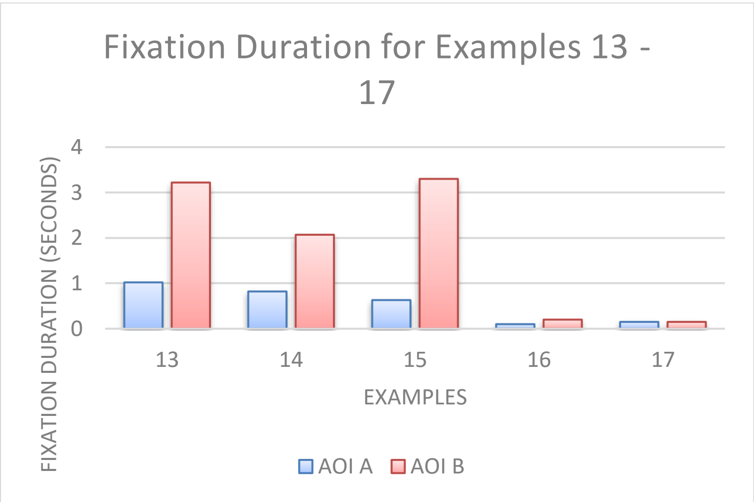


Figure 9: Fixation duration for AOI A and AOI B in Examples 13 - 17

The participant's total fixation duration in AOI A for all five examples was 2.72 seconds, with an average of 0.54 seconds per example. The total fixation duration for AOI B across all examples was 8.94 seconds, with an average of 1.79 per example.

<u>Summary</u>

The pilot study results indicated that the Tobii Studio software could successfully extract the results for both fixation count and fixation duration. The software could also separate data for AOI A and total AOI B, so that calculations could be made. Adjustments however had to be made to the data used for analysis. This included adding several variables (performance accuracy, total score fixations and AOI C) as well as using fixation percentages.

3.7 Ethical considerations

Ethical procedures required by Rhodes University were followed strictly. Permission was also received from the Rhodes University Student Bureau as well as the Department of Music and Performing Arts at Nelson Mandela University to conduct research with students from both universities. The ethical clearance letter for this study can be viewed as **Appendix H**.

After participants accepted an invitation to participate in the research, they were emailed an Informed Consent letter (**Appendix C**). This letter informed participants about the research process as well as their rights in the study. All participants had access to all aspects of the study and received no financial renumeration for their participation. All participants were informed that, should they wish to withdraw from the study at any point, they could do so without any risk. The letter also informed participants that the researcher would store all data for five years, and that the data would be used to complete a thesis and publish articles.

The researcher strove to pose no harm or threat to participants. Eye-tracking technology is safe and posed no threat to participants (Tobii, 2010b). The privacy of participants was protected by assigning aliases to them. Although each data collection session was recorded, the camera did not record faces. Participants were asked to give consent before video recording commenced. The researcher ensured the accuracy of the data by reporting the data fully and avoiding any omissions or modifications. Plagiarism was avoided by accurately referencing sources used.

3.8 Validity and reliability

According to McMillan & Schumacher (2010, p. 105), there are four types of validity that should be considered in quantitative research: statistical, internal, measurement and reliability.

In this study, statistical conclusion validity was ensured by using appropriate statistical tests to determine the significance of the relationships or differences between the two groups. A standardized protocol (**Appendix F**) was followed to increase statistical power. The Tobii Pro X2-60 Hz eye-tracker and Tobii Studio Software are also independent and reliable instruments of data collection.

The internal validity was strengthened by the similar nature of the participant groups. All participants regularly play the piano as one of their instruments. All participants achieved a minimum requirement of Grade 6 from various external examining bodies.

Measurement validity and reliability were ensured by using the calibration process completed by each participant before data collection began. The calibration is defined as the process whereby the eye-tracker matches the angle at which light is reflected from the eyes to the X-Y co-ordinates on the screen (Wilkinson & Mitchell, 2014).

3.9 Summary

This chapter provides a detailed presentation of the methodology followed in this quantitative empirical study. The research design was explained in detail. The selection of participants, data collection procedures, analytic procedures, pilot study, ethical considerations as well as reliability and validity were discussed.

Chapter 4 – Analysis

4.1 Introduction

The results of the study are presented in two main sections: Before presenting the main results, 4 examples are discussed because they were analysed separately in two groups. Examples 1 and 17 are discussed first, followed by Examples 11 and 12. The results for Test 1 and Results for Test 2 together with statistical inference of the data for each variable is presented next. The data is presented as graphs and each example is analysed and explained in detail. The results for five data categories are presented namely performance accuracy, fixations on entire scores, AOI A (fixations on key and time signature as a percentage of fixations on entire scores), AOI B (fixations on all deviations as a percentage of fixations on entire scores), and AOI C (two rule-based selected aspects in the examples). AOI C was included in the study to provide a control aspect against which the aspects isolated in this study can be compared. The total group results for all AOI are compared at the end for both tests. A short summary concludes the chapter. Since small sample groups lack statistical power, results should be interpreted with caution (McMillan & Schumacher, 2010).

4.2 Examples 1 and 17

Two examples (Examples 1 and 17) were included in this study because the researcher initially believed that they would provide a base-line score rather than any useful data. However, the results indicated that these two examples do provide interesting insights in themselves. The fact that they did not include any deviations, meant that they could not be analysed together with the rest of the examples which did contain deviations. The examples were both composed in C major and 4/4 time. The researcher decided to rather use two rule-based selected aspects of each example as a base line score.

4.2.1 Results for Examples 1 and 17

The results for Examples 1 and 17 are presented in this section. Since these two examples did not include any deviations, only four of the five main data categories of the main study can be used. These are performance accuracy, fixations on entire scores, AOI A and AOI C. For fixations on entire score, AOI A and C, both fixation count and fixation duration data are presented.

4.2.1.1 Performance accuracy for Example 1 and 17

Example 1 contained 30 notes. The average number of errors for Group A (expert) for this example was 0 notes and for Group B (amateur) 0.17 notes. The expert group therefore made 0% errors, while the amateurs made 0.1% errors in this example.

Example 17 contained 48 notes. In this example, the average number of errors for Group A (expert) was 0.9 notes and for Group B (amateur) 3.5 notes. This means that the expert sight-readers made 0.02% errors, while the amateur sight-readers made 0.7% errors in this example.

4.2.1.2 Results for fixations on entire scores

The results for gaze patterns on entire scores are presented next. The number of fixations on entire scores were added together for each group and divided by the number of participants in each group. The same procedure was used for duration of fixations. The mean fixation count and duration results for both groups are presented in **Figure 10** and **Figure 11**.

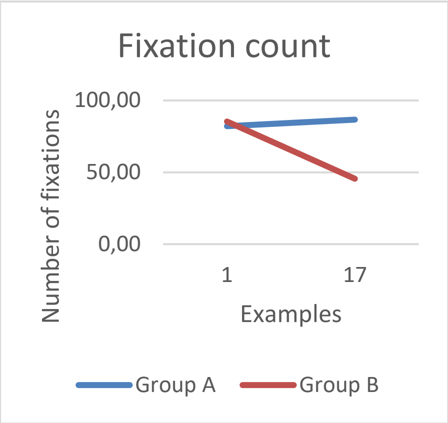


Figure 10: Fixation count on entire scores in Examples 1 and 17

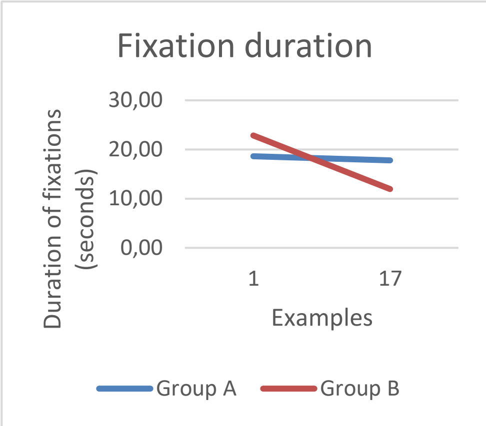


Figure 11: Fixation duration on entire scores in Examples 1 and 17

The results indicate that on average, Group B fixated 3.24 times longer and for 4.23 seconds longer on the entire score in Example 1 than Group A. In Example 17 however, Group A on average fixated 41.14 times more and for 5.84 seconds longer on the key and time signature aspects of the score.

4.2.1.3 Results for AOI A in Example 1 and 17

The results of AOI A are presented for both Examples 1 and 17. Due to the difference in total score results, each participant's fixations on AOI A was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI A. Results for mean percentage fixation count are presented first, followed by mean percentage fixation duration.

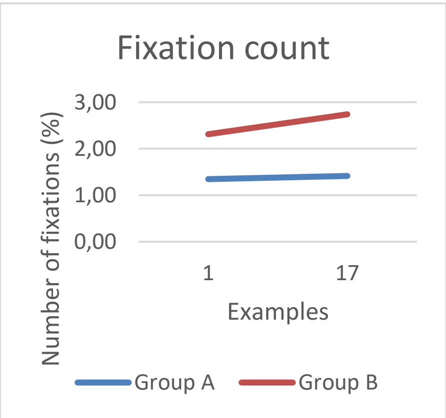


Figure 12: Mean percentage fixation count on AOI A in Examples 1 and 17

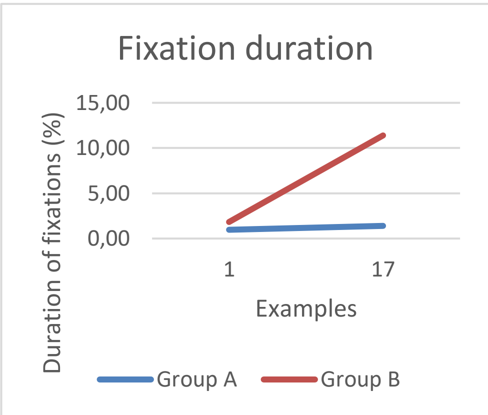


Figure 13: Mean percentage fixation duration on AOI A in Examples 1 and 17

The results indicate that Group B fixated 0.97% more and 4.23% longer on the key and time signature in Example 1 than Group A. In Example 17, Group B fixated 10% more and 1.32% longer on the key and time signature than Group A.

4.2.1.4 Results for AOI C

The results for AOI C are presented next. AOI C consists of two selected notes namely 1) G (the first note of bar 5 in Test 1 and the first note of bar 3 in Test 2) and 2) T (a randomly selected tonic note). Due to the difference in total score results, each participant's fixations on AOI C was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI C. Results for mean percentage fixation count are presented first, followed by mean percentage fixation duration.

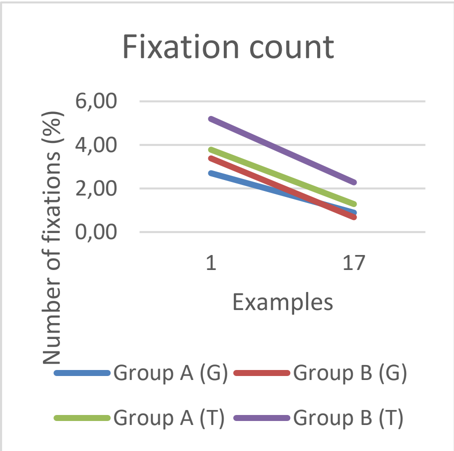


Figure 14: Mean percentage fixation count on AOI C in Examples 1 and 17

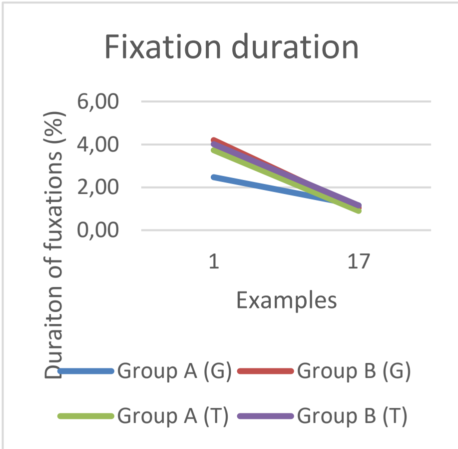


Figure 15: Mean percentage fixation duration on AOI C in Examples 1 and 17

The results for G indicate that Group B fixated 1.73% more and 0.68% longer on this note in Example 1 than Group A. In Example 17 however, Group A fixated 0.11% more and 0.21% longer on G than Group B. The results for T suggest that Group B fixated 1.41% more and 0.28% longer on this note in Example 1 than Group A. In Example 17, Group B fixated 1% more and 0.25% longer on this note than Group A.

4.3 Examples 11 and 12

Two further examples were initially included in the study in order to act as a base line score. These two examples were composed in F major and G major respectively. They did not contain any deviations. Analysis of the data analysis categories revealed that these two examples could not be compared to the examples of the main studies, due to the lack of deviations. The fact that they were not composed in C major, also made them incomparable with Examples 1 and 17. Examples 11 and 12 were thus analysed separately. Since neither example contained any deviations, only the performance accuracy, fixations on entire scores, AOI A and AOI C could be analysed. The results are presented next.

4.3.1 Results for Examples 11 and 12

The results for Examples 11 and 12 are presented next. Performance accuracies are presented first, followed by fixations on entire scores, AOI A and AOI C.

4.3.1.1 Performance accuracies for Examples 11 and 12

Example 11 contained 24 notes. The average number of errors for Group A (expert) was 0 notes and for Group B (amateur) 0.43. The expert group therefore made 0% errors for this example, while the amateurs made 2% errors.

Example 12 consisted of 14 notes. The average number of errors for Group A (expert) for this example was 0.09 notes and for Group B (amateur) 1 note. The expert sight-readers therefore made 1% errors and the amateurs made 7% errors in these examples.

4.3.1.2 Results for fixations on entire scores

The results for gaze patterns on entire scores are presented next. The number of fixations on entire scores were added together for each group and divided by the number of participants in each group. The same procedure was used for duration of fixations. The mean fixation count and duration results for both groups are presented in **Figure 16** and **Figure 17**.

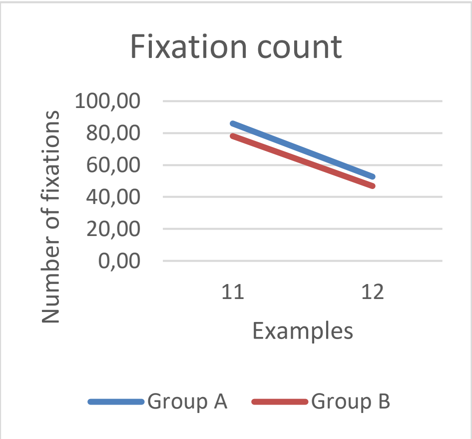


Figure 16: Fixation count on entire scores in Examples 11 and 12

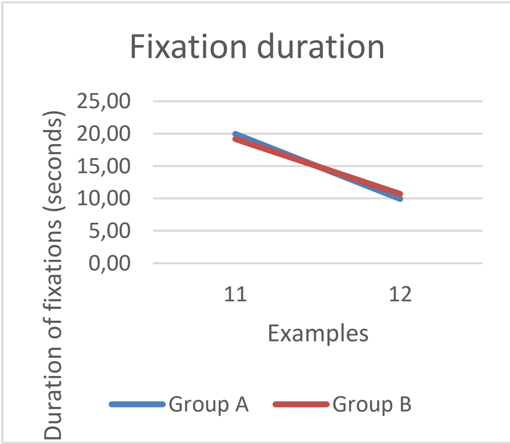


Figure 2: Fixation duration on entire scores in Examples 11 and 12

The results indicate that Group A fixated 13.73% more and 0.01% longer on the entire scores than Group B.

4.3.1.3 Results for AOI A in Examples 11 and 12

The results for AOI A in Examples 11 and 12 are presented next. Due to the difference in total score results, each participant's fixations on AOI A was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI A. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration (see **Figures 18** and **19**).

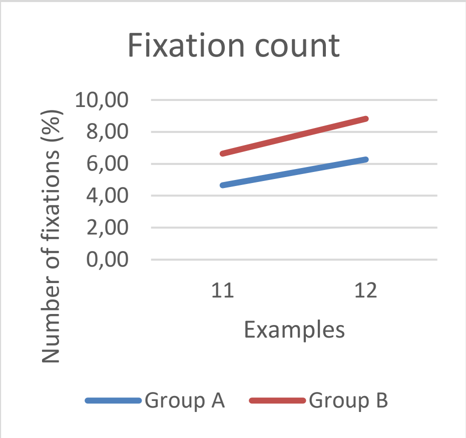


Figure 18: Mean percentage fixation count on AOI A in Examples 11 and 12

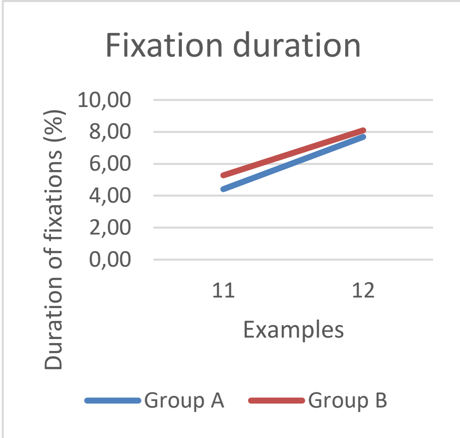


Figure 19: Mean percentage fixation duration on AOI A in Examples 11 and 12

The results indicate that Group B fixated 4.53% more and 1.28% longer on key and time signatures than Group A.

4.3.1.4 Results for AOI C in Examples 11 and 12

The results for AOI C in Examples 11 and 12 are presented next. Due to the difference in total score results, each participant's fixations on AOI C was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI C. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

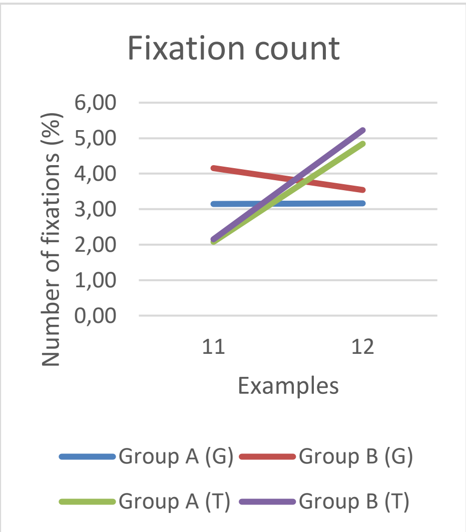


Figure 20: Mean percentage fixation count on AOI C in Examples 11 and 12

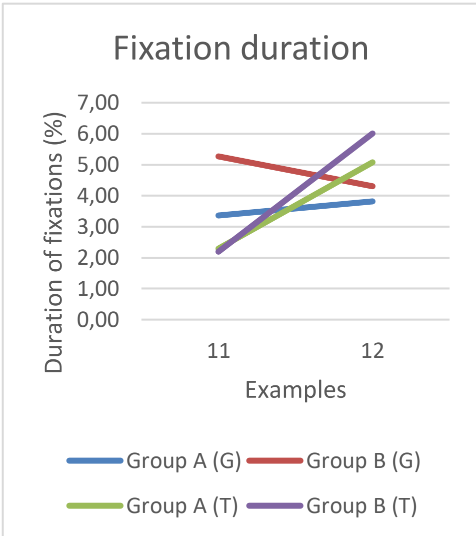


Figure 21: Mean percentage fixation duration on AOI C in Examples 11 and 12

The results for G indicate that Group B fixated 1.39% more and 2.39% longer on this note than Group A. Similarly, results for T indicate that Group B fixated 0.46% more and 0.83% longer on this note than Group A.

4.3 Results

This section presents the results of Test 1 and Test 2. Each test is divided into five focused categories of data; namely 1) performance accuracy, 2) Fixations on entire scores, 3) key and time signature (AOI A), 4) all deviations (AOI B) and 5) two distinct rule-based selected aspects of each score (AOI C). The first aspect is a tonic note and the second is the first note of bar 5 in Test 1. For Test 2, the first note of bar 3 is used as the second aspect. Results for AOI A, B and C are expressed as percentages of fixations on entire scores (to report proportion of fixations on these variables). All data captured in categories AOI A, AOI B and AOI C are measured according to two variables' namely fixation count and fixation duration.

4.3.1 Results for Test 1

The results for Test 1 are discussed in this section. First, the performance accuracy results for all examples will be presented. This is followed by results for fixations on entire scores, AOI A (key and time signature), AOI B (deviations) and AOI C (two rule-based selected aspects of each example).

4.3.1.1 Performance accuracy in Examples 2 - 10

The results of performance accuracy in Examples 2 – 10 can be seen in **Figure 22**. The results show the average number of correctly performed notes for each group, as well as the total number of possible notes for each example.

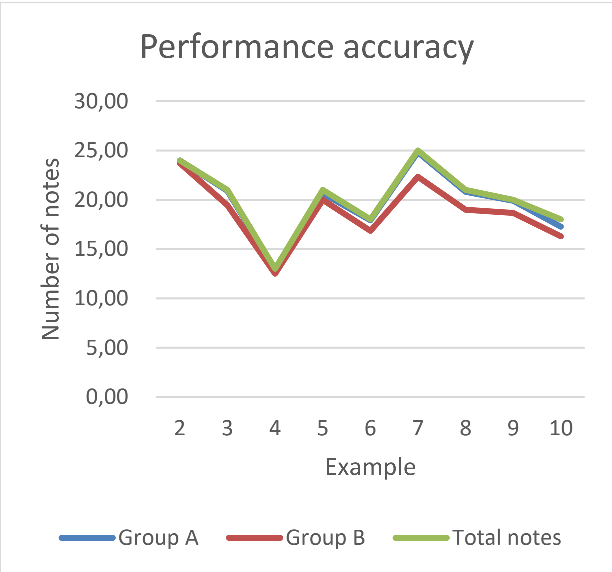


Figure 22: Performance accuracies in Examples 2 - 10

The results indicate that Group A (expert) on average made 1.84 errors out 181 notes. This amounts to 1.01%. Out of these errors, 0.19 (0.11%) were accidentals and 0.18 (0.10%) were change of time signature errors. Group B (amateur) on average made 12.24 errors out of 181 notes, which amounts to 6.76%. Out of these errors, 0.6 (0.33%) errors were accidentals and 1.24 (0.68%) were change of time signature errors (out of 13).

The mean for Group A was 0.01 and Group B was 0.07. The standard deviation for Group A was 0.000 and Group B was 0.001. According to the *t*-test, the difference between the two groups' total errors was significant (*t*[5.1332] = 10.64, p = 0.0001). The difference between the two groups' accidental errors (*t*[1.0523] = 11.19, p = 0.31484) and change of time signatures (*t*[1] = 8, p = 0.34659) was not significant at $p < 0.05$.

4.3.1.2 Results for fixations on entire scores

The results for gaze patterns on entire scores are presented next. The number of fixations on entire scores were added together for each group and divided by the number of participants in each group. The same procedure was used for duration of fixations. The mean fixation count and duration results for both groups are presented in **Figure 23** and **Figure 24**.

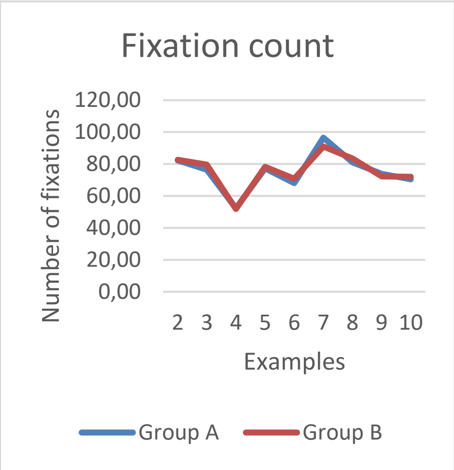


Figure 23: Fixation count on entire scores in Examples 2 - 10

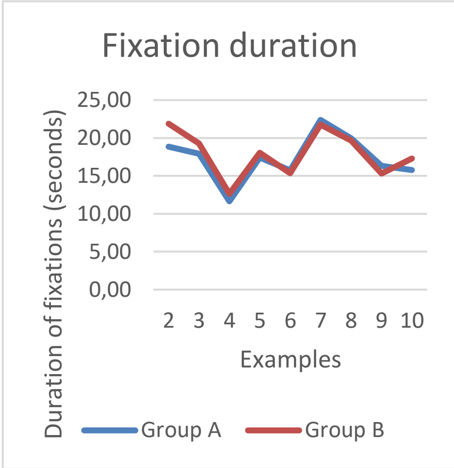


Figure 24: Fixation duration on entire scores in Examples 2 - 10

	Mean	**Standard Deviation**
Fixation count (Group A)	75.35	11.98
Fixation count (Group B)	75.75	11.09
Fixation duration (Group A)	17.34	3.03
Fixation duration (Group B)	17.91	3.11

The results seem to indicate that Group B fixated 3.52% more and for 5.15% longer on entire scores than Group A. However, according to the *t*-test for fixation count ($t[0.0719] = 15.91$, $p = 0.94354$) and fixation duration ($t[0.3497] = 15.99$, $p = 0.69758$) the difference between the two groups is not significant at $p < 0.05$.

4.3.1.3 Results for AOI A in Examples 2 – 10

The results for AOI A are presented next. Due to the difference in total score results, each participant’s fixations on AOI A was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI A. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation count results for AOI A were added together for each group, then divided by the number of participants in each group (see **Figure 25**). The same process was followed for mean percentage fixation duration. The results are in seconds and illustrated in **Figure 26.**

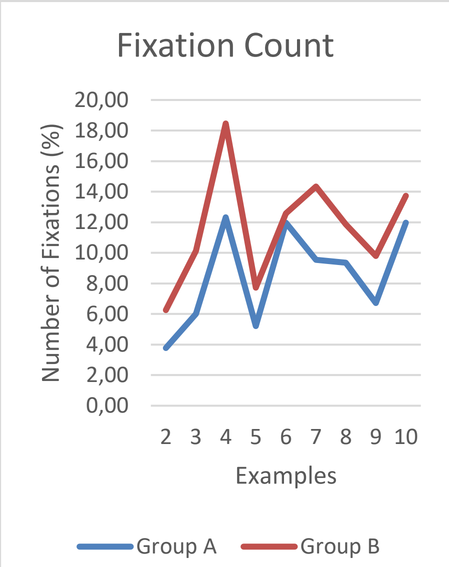


Figure 25: Mean percentage fixation count on AOI A in Examples 2 - 10

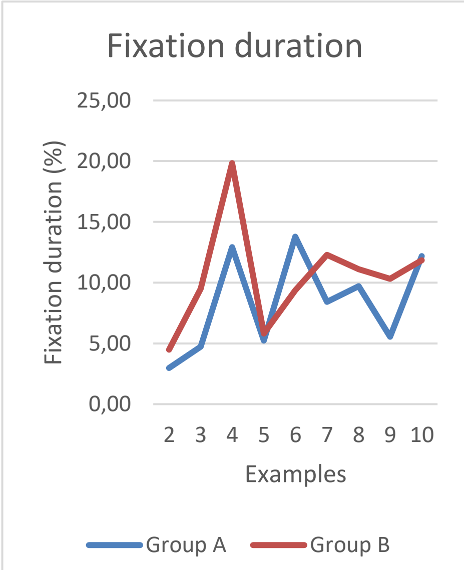


Figure 26: Mean percentage fixation duration on AOI A in Examples 2 - 10

	Mean	**Standard Deviation**
Fixation count (Group A)	8.54	3.22
Fixation count (Group B)	11.65	3.7
Fixation duration (Group A)	8.39	3.98
Fixation duration (Group B)	10.51	4.37

The results seem to indicate that Group B fixated 28.02% more and 19.05% longer on the key and time signatures aspects of Examples in Test 1. However, the *t*-test for fixation count (*t*[1.9044] = 15.71, p = 0.07533) and fixation duration (*t*[1.0739] = 15.86, p = 0.29894) indicate that the difference between the two groups is not significant at $p < 0.05$.

4.3.1.4 Results for AOI B in Examples 2 - 10

The mean percentage fixation count and duration on AOI B (all deviations) for both groups for Examples 2 – 10 is presented next. Due to the difference in total score results, each participant's fixations on AOI B was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI B. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation counts for AOI B were added together for each group, then divided by the number of participants in each group. The results are detailed in **Figure 27.** The same process was followed for fixation duration. The results are in seconds and illustrated in **Figure 28**.

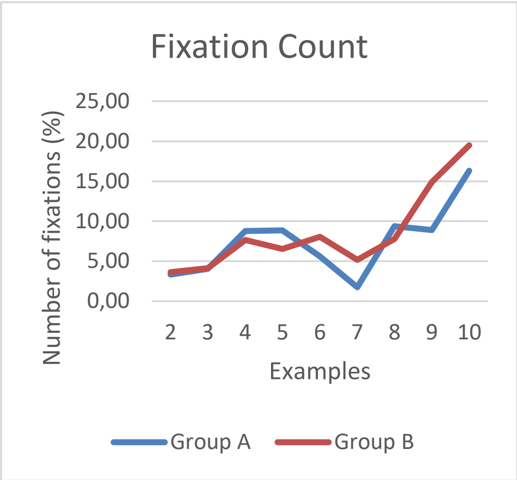


Figure 27: Mean percentage fixation count on AOI B in Examples 2 - 10

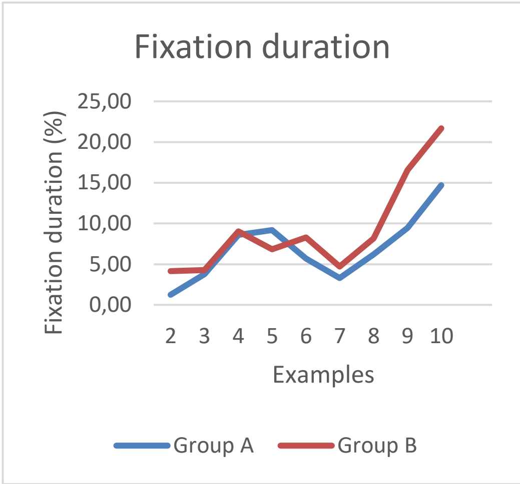


Figure 28: Mean percentage fixation duration on AOI B in Examples 2 - 10

	Mean	**Standard Deviation**
Fixation count (Group A)	7.34	4.37
Fixation count (Group B)	8.59	5.25
Fixation duration (Group A)	6.9	4.07
Fixation duration (Group B)	9.3	6.0

The results seem to indicate that Group B fixated 10.41% more and for 21.61% longer on all deviations than Group A. However, the *t*-test for fixation count (*t*[0.5080] = 15.48, p = 0.61859) and fixation duration (*t*[0.99] = 14.07, p = 0.33684) indicate that the difference between the two groups was not significant.

4.3.1.5 Results for AOI C in Examples 2 – 10

The results for AOI C are presented next. AOI C consisted of two rule-based selected notes from each score labelled G and T respectively. G is the first note of bar 5 and T is a randomly selected tonic note from each example. Due to the difference in total score results, each participant's fixations on AOI C was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI C. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation counts for G were added together and divided by the number of participants in each group. The same procedure was followed for T. The results are presented in **Figure 29**. The results for mean percentage fixation duration can be seen in **Figure 30**.

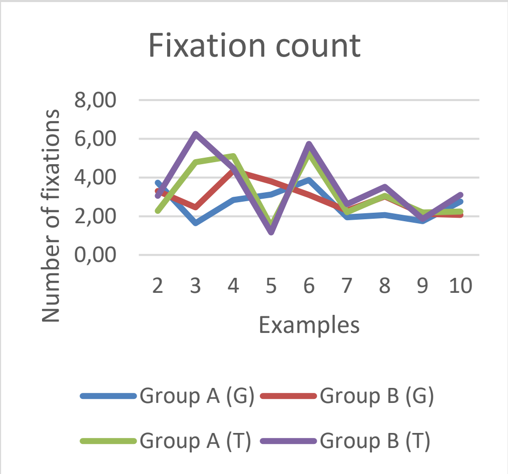


Figure 29: Mena percentage fixation count on AOI C in Examples 2 - 10

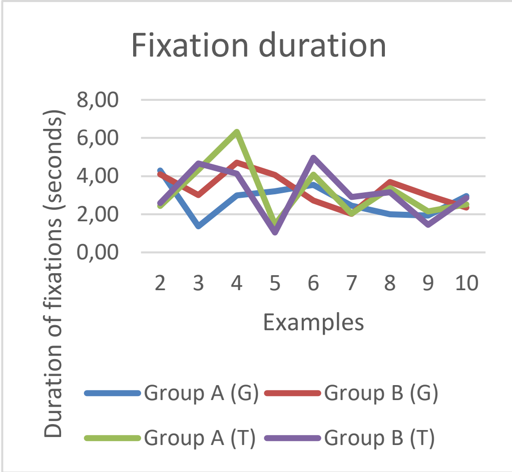


Figure 30: Mean percentage fixation duration on AOI C in Examples 2 - 10

	Mean (G)	**Standard Deviation (G)**	**Mean (T)**	**Standard Deviation (T)**
Fixation count (Group A)	2.63	0.84	3.18	1.46
Fixation count (Group B)	2.95	2.95	3.53	1.69
Fixation duration (Group A)	2.75	0.9	3.19	1.52
Fixation duration (Group B)	3.29	3.29	3.08	1.34

The results for G indicate that Group B fixated 2.86% more and for 4.91% longer than Group A. The results for T indicate that Group B fixated 3.16% more than Group A, however Group fixated 0.97% longer than Group B. The *t*-test for G fixation count *(t*[0.8282] = 15.94, p = 0.41981) and fixation duration (*t*[1.29] = 16, p = 0.21607) indicate no significant group difference on this note. Similarly, the *t*-test for T fixation count (*t*[0.4712] = 15.68, p = 0.64396) and duration (*t*[0.16] = 15.75, p = 0.87452) indicate no significant difference between the two groups on this note.

4.3.2 Results for Test 2

The results for Test 2 are presented next. First, the performance accuracy results for all examples will be presented. This is followed by results for fixations on entire scores, AOI A (key and time signature), AOI B (deviations) and AOI C (two rule-based selected aspects from each example).

4.3.2.1 Performance accuracy in Examples 13 - 16

The results of performance accuracy in Examples 13 - 16 can be seen in **Figure 31**. The results show the average number of correctly performed notes (and rests) for each group, as well as the total number of possible notes (and rests) for each example.

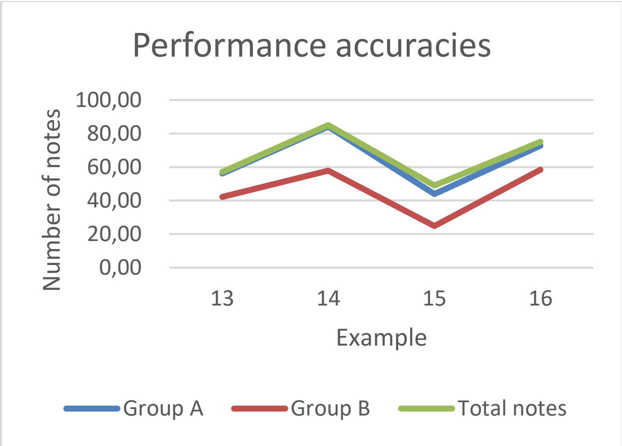


Figure 31: Performance accuracies in Examples 13 - 16

The results indicate that Group A (expert) on average made 9.11 errors out 266 notes. This amounts to 3.42 %. Out of these errors, 0.18 (0.07%) were accidentals and 0 (0%) were change of time signature errors. Group B (amateur) on average made 82.77 errors out of 266 notes, which amounts to 31.12%. Out of these errors, 3.69 (1.39%) errors were accidentals and 1.07 (0.4**%**) were change of time signature errors.

The mean for Group A was 0.04 and Group B was 0.32. The standard deviation for Group A was 0.04 while Group B was 0.12. The *t*-test indicates that the difference between the two groups' total errors was significant (*t*[4.4453] = 3.78, p = 0.01284). However the *t*-test for accidental errors (*t*[1.5629] = 3.08, p = 0.21375) and time signature change errors (*t*[1] = 3, p = 0.391) shows no significant difference between the two groups.

4.3.2.2 Results for fixations on entire scores in Examples 13 – 16

The results for gaze patterns on entire scores are presented next. The number of fixations on entire scores were added together for each group and divided by the number of participants in each group. The same procedure was used for duration of fixations. The mean fixation count and duration results for both groups are presented in **Figure 32** and **Figure 33**.

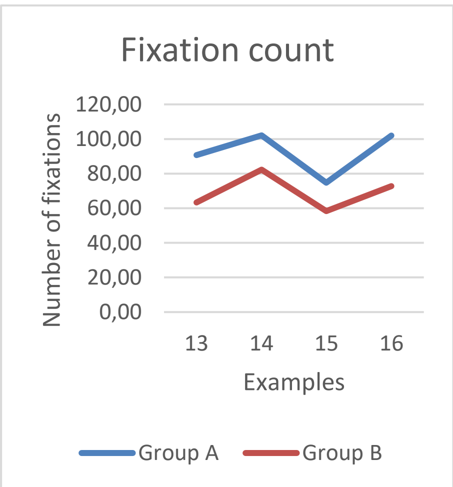


Figure 32: Fixation count on entire scores in Examples 13 - 16

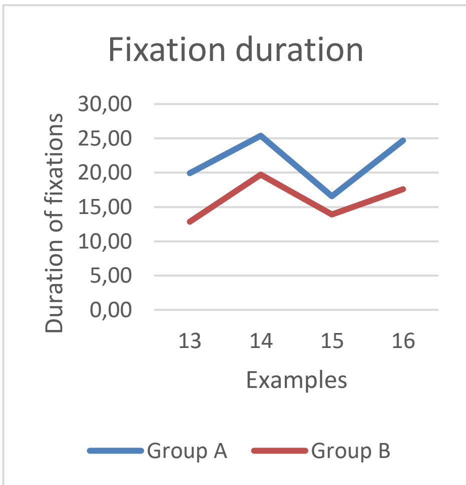


Figure 33: Fixation duration on entire scores in Examples 13 - 16

	Mean	Standard Deviation
Fixation count (Group A)	92.37	12.93
Fixation count (Group B)	69.81	10.06
Fixation duration (Group A)	21.64	4.16
Fixation duration (Group B)	16.01	3.19

The results seem to indicate that Group fixated 92.76% more and 22.5% longer on entire scores than Group B. The *t*-test for fixation count shows a significant difference between Group A and B (*t*[2.7735] = 5.78, p = 0.03358). Interestingly, the *t*-test for fixation duration shows no significant difference between Group A and B (*t*[2.145] = 5.62, p = 0.07868).

4.3.2.3 Results for AOI A in Examples 13 - 16

The results for AOI A are presented next. Due to the difference in total score results, each participant's fixations on AOI A was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI A. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation count on AOI A (key and time signature) for both groups for Examples 13 – 16 is presented first. The fixation counts for AOI A were added together for each group, then divided by the number of participants in each group (see **Figure 34**). The same process was followed for fixation duration and the results can be seen in **Figure 35.**

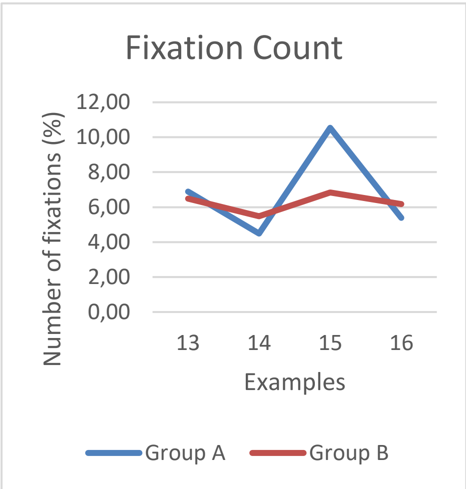


Figure 34: Mean percentage fixation count on AOI A in Examples 13 - 16

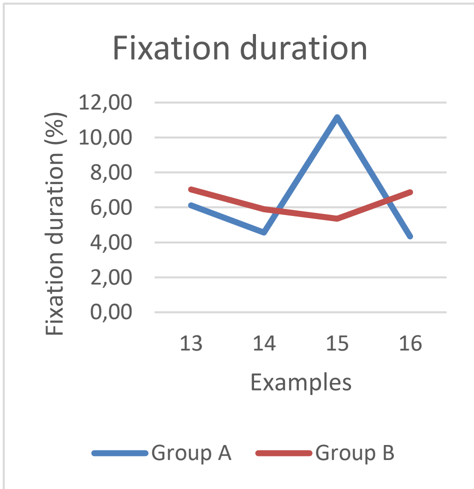


Figure 35: Mean percentage fixation duration on AOI A in Examples 13 - 16

	Mean	Standard Deviation
Fixation count (Group A)	6.83	2.67
Fixation count (Group B)	6.25	3.18
Fixation duration (Group A)	6.55	0.58
Fixation duration (Group B)	6.29	0.8

The results seem to indicate that Group A fixated 2.32% more and 1.04% longer on key and time signatures than Group B. However, the *t*-test for fixation count (*t*[0.4251] = 3.28, p = 0.69709) and fixation duration (*t*[0.16] = 3.38, p = 0.80957) shows no significant difference between the two groups.

4.3.2.4 Results for AOI B in Examples 13 - 16

The results for AOI B (all deviations) are presented next. Due to the difference in total score results, each participant's fixations on AOI B was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI B. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation on AOI B (all deviations) for both groups in Examples 13 – 16 is presented next. The mean percentage fixation counts for AOI B were added together for each group then divided by the number of participants in each group (see **Figure 36**). The same process was followed for fixation duration, and the results can be seen in **Figure 37**.

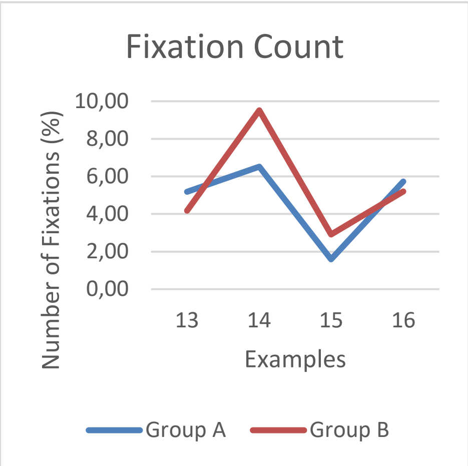


Figure 36: Mean percentage fixation count on AOI B in Examples 13 - 16

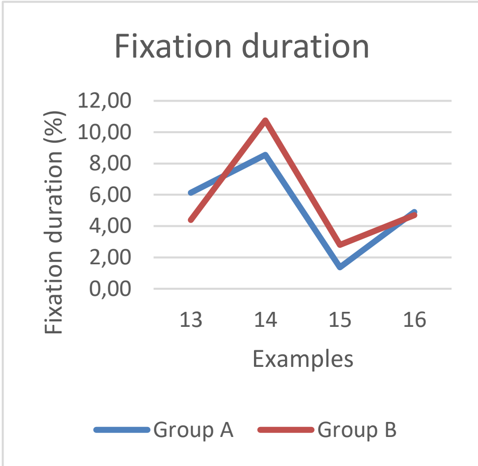


Figure 37: Mean percentage fixation duration on AOI B in Examples 13 - 16

	Mean	**Standard Deviation**
Fixation count (Group A)	4.75	2.18
Fixation count (Group B)	5.45	2.87
Fixation duration (Group A)	5.24	2.99
Fixation duration (Group B)	5.66	3.49

The results indicate that Group B fixated 2.8% more and for 1.7% longer on deviations than Group A. However, the *t*-test for fixation count (*t*[0.3888] = 5.6, p = 0.71174) and fixation duration (*t*[0.18] = 5.86, p = 0.80565) indicates no significant difference between the two groups.

4.3.2.5 Results for AOI C in Examples 13 – 16

The results for AOI C are presented next. AOI C consisted of two rule-based selected notes from each score. G is the first note of bar 3 and T is a randomly selected tonic note from each example. Due to the difference in total score results, each participant's fixations on AOI C was calculated as a percentage of their total score fixations. The same procedure was followed for time focused on AOI C. Results for mean percentage fixation count is presented first, followed by mean percentage fixation duration.

The mean percentage fixation counts for G were added together and divided by the number of participants in each group. The same procedure was followed for T. The results are presented in **Figure 38** and **Figure 39**.

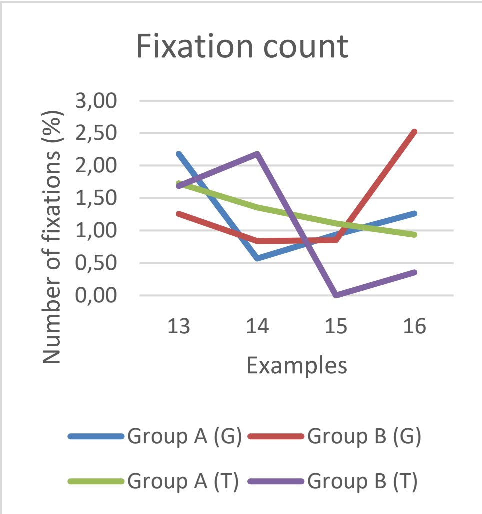


Figure 38: Mean percentage fixation count on AOI C in Examples 13 - 16

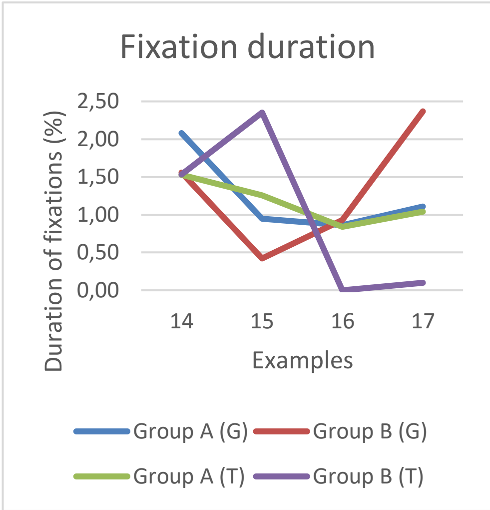


Figure 39: Mean percentage fixation duration on AOI C in Examples 13 - 16

	Mean (G)	Standard Deviation (G)	Mean (T)	Standard Deviation (T)
Fixation count (Group A)	1.24	0.67	1.28	0.34
Fixation count (Group B)	1.37	0.79	1.06	1.04
Fixation duration (Group A)	1.25	0.56	1.17	0.3
Fixation duration (Group B)	1.32	0.84	1.0	1.14

The results for G indicate that Group B fixated 0.53% more and for 0.28% longer on this note than Group A. The results for T seem to indicate that Group A fixated for 0.9% more and 0.68% longer on this note than Group B. However, the *t*-test for G fixation count (*t*[0.2506] = 5.89, p = 0.81061) and fixation duration (*t*[0.14] = 5.25, p = 0.87355) indicate no significant difference between the two groups on this note. Similarly, the *t*-test for T fixation count (*t*[0.4107] = 3.64, p = 0.70432) and fixation duration (*t*[0.29] = 3.4, p = 0.97584) indicate no significant difference between the two groups.

4.3.3 Comparison of AOI results

The results for all AOI are compared and presented next. The total group fixation count on AOI A, B and C (G and T) are presented for both tests to establish whether there is a hierarchical order of fixation patterns. These total scores represent each group's total score across all examples in each test.

4.3.3.1 Results for Test 1

The total group mean percentage fixation count and fixation duration results for AOI A, B and C (G and T) are presented first and can be seen in **Figure 40** and **41**.

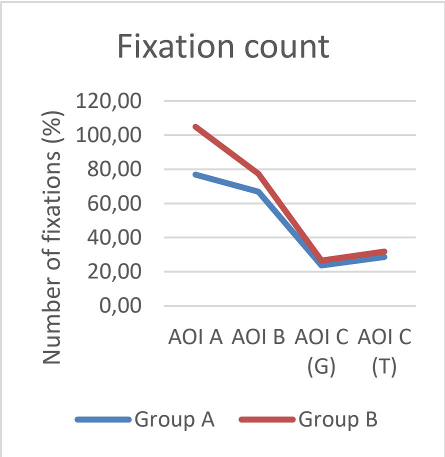


Figure 40: Comparison of total mean percentage fixation count on all AOI in Examples 2 - 10

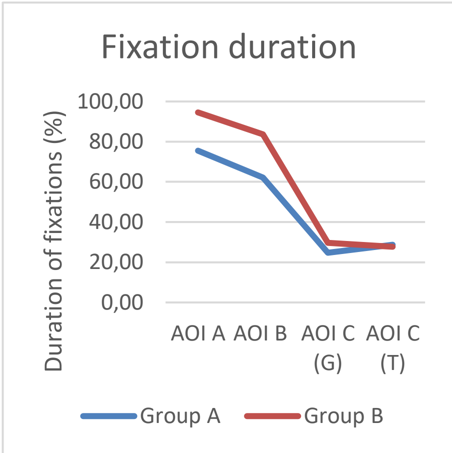


Figure 41: Comparison of total mean percentage fixation duration on all AOI in Examples 2 - 10

The results indicate that the expert group fixated 9.93% less on AOI B across all examples than on AOI A and 13.44% shorter. Similarly, the amateur group fixated 27.54% less frequently on AOI B across all examples than on AOI A and 10.88% shorter. However, AOI B contained more aspects than AOI A (there were more than one deviation in several examples) which makes these results difficult to compare empirically. The *t*-test for fixation count (*t*[0.61] = 14.72, p = 0.27519) and fixation duration (*t*[0.79] = 15.99, p = 0.22122) indicates no significant difference between the two variables for Group A. A similar finding was found for Group B with a *t*-test for fixation count (*t*[0.1.43] = 14.36, p = 0.08609) and fixation duration (*t*[0.49] = 14.64, p = 0.31598) indicates no significant difference between the two groups. If sight-reading examples are used with only one deviation in the future, this result may very well turn out to be statistically significant. It may still be worth noting that both participant groups fixated more on AOI A (which is only one aspect of the score) than on AOI B (which includes more aspects of the scores than AOI A).

When comparing AOI A with AOI C (G), the results indicate that the expert sight-readers fixated 53.15% less on G across all examples than on AOI A and 50.79% shorter. Similarly, the amateur sight-readers fixated 78.32% less on G than on AOI A across all examples and 64.93% shorter. Interestingly, the *t*-test for fixation count (*t*[5.32] = 9.08, p = 0.00003) and fixation duration (*t*[4.15] = 8.82, p = 0.00038) indicates that this difference is significant. The *t*-test for fixation count (*t*[0.6.91] = 8.72, p = 0.0000) and fixation duration (*t*[4.85] = 8.67, p = 0.00009) indicates that this difference is also significant for the amateur sight-readers.

Similarly, when comparing AOI A to T, the results indicate that the expert sight-readers fixated 48.23% less on T across all examples than on AOI A and 46.82% shorter. Likewise, the amateur sight-readers fixated 73.09% less on T than AOI A across all examples and 66.85% shorter. The *t*-test for fixation count (*t*[4.54] = 11.16, p = 0.00017) and fixation duration (*t*[3.67] = 10.28, p = 0.000104) indicates that this difference is significant for the expert sight-readers. The *t*-test for fixation count (*t*[6] = 11.2, p = 0.00001) and fixation duration (*t*[4.87] = 9.48, p = 0.00009) indicates that this difference is also significant for the amateur sight-readers. This indicates that both sight-reader groups fixated significantly less on both aspects of AOI C than on AOI A.

4.3.3.2 Results for Test 2

The total group mean percentage fixation count and fixation duration results for AOI A, B and C (G and T) are presented next. These can be seen in **Figure 42** and **43**.

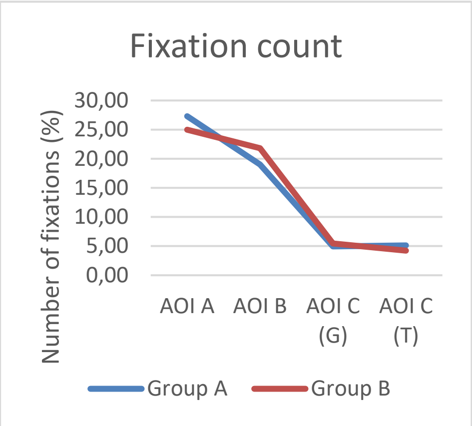


Figure 42: Comparison of total mean percentage fixation count on all AOI in Examples 13 - 16

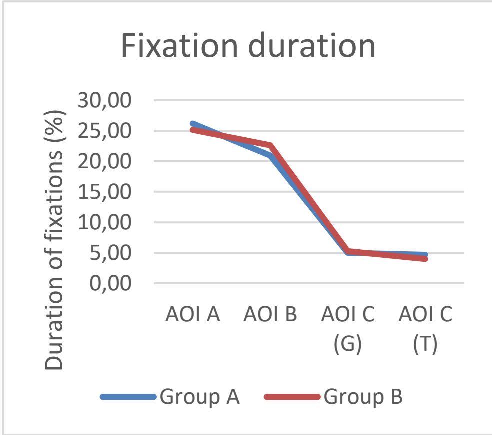


Figure 43: Comparison of total mean percentage fixation duration on all OAI in Examples 13 - 16

The results indicate that the expert sight-readers fixated 8.29% less on AOI B than AOI A across all examples and 5.24% percent shorter. Likewise, the amateur sight-readers fixated 3.17% less on AOI B than on AOI A across all examples and 2.5% shorter. These results are incomparable for the same reasons as stated for Test 1. The *t*-test for fixation count (*t*[0.61] = 14.72, p = 0.27519) and fixation duration (*t*[0.79] = 15.99, p = 0.22122) indicates that this difference is not significant for expert sight-readers. Similarly, the *t*-test for fixation count (*t*[0.54] = 3.24, p = 0.30371) and fixation duration (*t*[0.35] = 3.31, p = 0.36970) indicates that this difference is likewise not significant for amateur sight-readers. Once again, this difference may well be significant if only one deviation is compared to a key and time signature aspect of a music score.

When comparing the results of AOI A to G, the expert sight-readers fixated 22.35% less on G than on AOI A across all examples and 21.2% shorter. Equally, the amateur sight-readers fixated 19.515 less on G than on AOI A across all examples and 19.87% shorter. The *t*-test for fixation count (*t*[4.06] = 3.4, p = 0.00334) and fixation duration (*t*[3.28] = 3.19, p = 0.00838) indicates that this difference is significant for the expert sight-readers. Similarly, the *t*-test for fixation count (*t*[9.92] = 5.49, p = 0.00003) and fixation duration (*t*[8.56] = 5.99, p = 0.00007) indicates that this difference is also significant for the amateur sight-readers.

The results for T also indicate that the expert sight-readers fixated 22.17% less on T than on AOI A across all examples and 21.52% shorter. Also, the amateur sight-readers fixated 20.75% less on T than on AOI A across all examples and 21.17% shorter. The *t*-test for fixation count (*t*[4.12] = 3.1, p = 0.00310) and fixation duration (*t*[3.37] = 3.05, p = 0.00751) indicates that this difference is significant for the expert sight-readers. Likewise, the *t*-test for fixation count (*t*[8.69] = 4.69, p = 0.00006) and fixation duration (*t*[7.58] = 5.37, p = 0.00014) indicates that this difference is likewise significant for the amateur sight-readers.

4.4 Summary

In this chapter, the results of both tests were discussed. Graphs were used to depict the differences between Group A (expert) and Group B (amateur) for all categories of data (performance accuracies, fixations on entire score, AOI A, AOI B and AOI C). Both variables for these categories were displayed (fixation count and fixation duration). Statistical inference was also discussed. The results indicate no significant difference between the two groups for all variables except performance accuracies for both tests, as well as fixation count on total scores for Test 2. The results for all AOI categories were also compared for both groups. These indicate a significant difference between the fixation patterns on AOI A and AOI C for both groups. The difference between fixation patterns on AOI A and AOI B are insignificant.

Chapter 5 – Discussion

5.1 Introduction

This study investigates the effects of key and time signatures, as well as deviations to a score, on the fixation patterns of expert and amateur sight-readers. To date, very little empirical research exists that explores the effects of these aspects of music sight-reading. The results in this chapter will be discussed according to the following variables; 1) performance accuracies, 2) total score fixations, 3) key and time signatures, 4) deviations, 5) randomly selected notes as base line score and 6) comparison of AOI results.

5.2 Performance accuracies

The results for performance accuracies are discussed in this section. Each participant's performance for all examples was assessed by the researcher. The total number of notes in each example was calculated, together with each participant's number of correctly performed notes in each example. In order for a note to be marked correctly, both the pitch and rhythm element had to be performed correctly. The results for Examples 1 and 17 are discussed first, followed by Examples 11 and 12, Test 1 and finally Test 2.

5.2.1 Examples 1 and 17

As stated in the methodology section of this thesis, Examples 1 and 17 were both composed in C major. Example 1 was composed to be performed with the right hand only, while Example 17 was composed to be performed with both hands. Neither of the examples contained any deviations (accidentals or changes of time signature). As the researcher was unsure of the results any of the examples would yield, these examples were initially included in the analysis. However, it became apparent that the absence of deviations in these two examples made their results incomparable with the other examples. The specific results of these two examples did however provide some interesting insights into various reading processes, which is why they are nonetheless included in this manuscript.

When the performance accuracy results for Examples 1 and 17 examples are compared, it indicates that the experts made no mistakes in either example. There was only one other example in which the experts made no mistakes (Example 11). This example will be discussed in the next section. Interestingly, there are no examples in which the amateurs made no errors.

The amateurs' percentage errors in Examples 1 and 17 was however relatively low (0.01% and 0.07% respectively). This low margin of error could possibly be prescribed to the low level of complexity of the examples. C major on the piano could perhaps be perceived as relatively easy, as there are no flats or sharps in the key signature. Participants could therefore focus on natural notes only. It would be interesting to research whether this finding is true for instruments other than the piano. The researcher plays the violin as a second instrument, and from personal experience, C major is not an easy key for the violin. Most beginner violin methods begin with keys like A major and D major. Sight-reading examples in C major on other instruments may therefore not necessarily produce such low amounts of errors as are reflected in these results.

The time signature for both these examples was 4/4, which could also have been perceived as a relatively easy metre to perform (if compared to 5/4 for example). Once again it would be interesting to compare these results to sight-reading on different instruments. It could be argued that time signatures (indicating metre) imply rhythmic aspects of music reading and performing which are not necessarily constricted to instrument-specific technical capacities.

Rhythms in Western Tonal music is broken down into various standardised patterns (crotchets, quavers, and the like) which do not necessarily change with metre. The tempo could maybe have a bigger influence on errors here, as faster notes may need more expertise to perform correctly. In these tests, the tempo was kept constant with the use of a metronome, and therefore was not a dependent variable.

These two examples did not include any deviations (accidentals or change of time signature). It would be interesting to research whether the presence of such deviations would affect this high level of accuracy.

In summary, the results for these examples indicate that both expert and amateur sight-readers appear to be comfortable performing in C major and 4/4 time on the piano, as they both perform with a high level of accuracy. Future research could investigate these findings on other instruments.

5.2.2 Examples 11 and 12

Examples 11 and 12 were composed in F major and G major respectively. Both examples were composed for the right hand only. Once again, the researcher was unsure what kind of results these two examples would yield, so they were initially included in the main analysis. The absence of any deviations meant that these two examples had to be analysed separately.

The results indicate very low percentage of errors for both Group A and B (0.01% and 0.09% respectively). This low margin of error could possibly be prescribed to the low level of complexity of these two examples. This could in turn be due to the fact that the examples were composed for one hand only. Since these results were not known during the planning phase of this study, Test 2 did not include any examples in these two keys. Future studies could investigate these results when applied to more complex sight-reading exercises for both hands.

The keys of F major and G major contain one flat and one sharp respectively in the key signature. The low amount of errors may suggest that pianists perceive these two keys as relatively simple keys in which to perform. It is once again debatable whether these results are applicable to instruments other than the piano.

There were no deviations (accidentals or changes of time signature) present in either example. The lack of deviations may have added to the low complexity of these two examples. Interestingly, one other example in Test 1 was also composed in F major (Example 9). This example however included four changes of time signature. For this example, the experts' average performance accuracy was similar to Example 12 (0.09 errors). The amateur's accuracy was also relatively low (1.33 errors). This suggests that F major, with or without deviations may be perceived as relatively easy by pianists.

In summary, the results for Example 11 and 12 indicate that both expert and amateur sight-readers appear to be relatively comfortable sight-reading and performing in F major and G major. Future research could investigate these findings in more complex sight-reading tasks for both hands, as well as sight-reading tasks for other instruments.

5.2.3 Test 1

The examples in Test 1 were composed in various major keys and time signatures. Each example was composed to be performed with the right hand only.

When the results for both groups' performance accuracies are compared, it indicates a significant difference in the total errors for Group A and Group B. This in turn shows that Group

B made significantly more errors in their performances than Group A. This difference in performance errors could be due to a slight increase in complexities in some of these examples.

When the results are inspected, it appears that the experts on average made less than one mistake in each of the examples. In contrast, there are only two examples in which the amateurs on average made less than one mistake (Examples 2 and 4). Example 2 was composed in G major and contained one accidental, while Example 4 was composed in A major and included two accidentals. It is interesting to note that Example 4 resulted in such a low error result for the amateurs, as one would expect that three sharps would be perceived as relatively complex to perform. Besides Example 2 and 4, the amateurs made more than one mistake in all other examples in Test 1.

In contrast, the two examples which exhibited the greatest amount of errors for both groups were Examples 7 and 8. The expert sight-readers on average made 0.18 errors and the amateurs made 2.67 errors. Example 7 was composed in E-flat major and in 5/4. The three flats in the key signature may have presented some sight-readers with planning and performance challenges, resulting in a relatively higher margin of errors when compared with other examples. The time signature of Example 7 may also have contributed to the number of rhythmic errors. Students learning sight-reading often find 5/4 a complex metre to perform, possibly due to the irregular subdivision of each bar. Future research could investigate the impact of 5/4 on sight-reading performances in more detail.

In Example 8, the expert sight-readers on average made 0.2 errors, while the amateurs on average made 2 errors. The example was composed in E major (containing four sharps) and in 4/4. If compared to Examples 1 and 17, it is unlikely that the time signature contributed to the relatively high level of errors in the amateurs' performances. It could be speculated whether E major was perceived as a relatively complex key signature, resulting in more difficult planning, and performing.

The results for specific deviations (accidentals and change of metre) indicate relatively low percentage of errors. The results also suggest no significant difference between the errors made on deviations by Group A and Group B. This submits that the deviations in Examples 2 to 10 did not contribute significantly to the overall performance errors.

In summary, the results indicate that the amateur sight-readers made significantly more errors in Test 1 than the experts, which means that the expert sight-readers' sight-reading strategy resulted in more successful performances.

5.2.4 Test 2

The Examples in Test 2 were composed in various major keys and in several time signatures. All examples included deviations (accidentals and changes of time signature). The examples were all composed to be performed with both hands.

When the results for performance accuracy is compared, it indicates a significant difference in performance errors between Group A and B. This means that Group B made significantly more mistakes (31.12%) in their overall performances than Group A.

This significant difference could be the result of the high complexities of the examples. The study by Kopiez and Lee (2006) suggests that changing complexity of sight-reading stimuli may require adaptation of sight-reading strategy by readers.

Several studies have commented on the sight-reading strategies employed by expert and amateur sight-readers (Arthur et al. 2016; Drai-Zerbib et al. 2011; Fourie, 2004a; Huovinen et al. 2018; Sloboda, 1974; Wolf, 1976). They posit that expert sight-readers use pattern recognition, audiation, prediction skills and an increased eye-hand span to facilitate sight-reading. In contrast, amateur sight-readers tend to fixate on each note in succession. The experts' sight-reading strategy (which includes planning, reading, and performing) appears to have yielded more successful results in this study. In contrast, the reading strategy of the amateurs resulted in less successful performances. The sight-reading strategies of Group A and B could therefore also have influenced this result.

The example with the lowest number of errors for both groups was Example 13. The experts on average made 0.82 errors, while the amateurs on average made 14.86 errors. This example was composed in B-flat major (containing only two flats) and in 4/4. There were two accidentals included in this example. It could perhaps be argued that only two flats may have been perceived as relatively simple by both experts and amateurs, resulting in fewer errors. The difference between the two groups' errors on accidentals was not significant and may therefore not have contributed to the overall error count.

The two examples which yielded the highest percentage of errors for both groups are Example 14 and 15. Example 14 was composed in E major and 3/2 time. The experts on average made 0.9 errors in this example, while the amateurs on average made 27.14 errors. Both the key and time signature aspects of this example may have been perceived as complex by sight-readers. The example also included multiple accidentals, further contributing to the complexity of the performances.

Similarly, Example 15 was composed in B major and in 3/4 time. The expert sight-readers on average made 5.09 errors for this example, while the amateurs on average made 24.17 errors. Interestingly, the A # in the key signature provided numerous participants (both expert and amateur) with difficulty, as they performed A naturals instead. This could be investigated in future research, whether the problem is universal for this tonality or restricted to these participants. Nevertheless, both groups made several errors in this example, suggestion that demands were placed on sight-reading strategies that resulted in less successful performances than other examples.

One can conclude from the results that the expert sight-readers' sight-reading strategy (planning, reading, and performing) was significantly more successful than the amateurs' strategy for the examples in Test 2. This result will be interrogated further in the sections dealing with the other variables in this study to find a possible reason for this difference. The same finding was true for Test 1. Examples 1, 17, 11 and 12 however presented insignificant differences between expert and amateur errors.

5.3 Total score fixations

The results for total score fixations are discussed next. The total score fixations refers to 1) the total number of times each participant fixated on each entire score and 2) the total length of time each participant gazed at each entire score. Each participant's total fixation count and duration for every example was recorded. Each group's total fixations were added together and divided by the number of participant's in each group. This provided the researcher an average total fixation count and duration for each group, which could be compared and discussed. The results for Examples 1 and 17 are discussed first, followed by Examples 11 and 12, Test 1 and finally Test 2.

5.3.1 Examples 1 and 17

As stated before, Examples 1 and 17 were both composed in C major and in 4/4 time. Example 1 was composed for the right hand only, while Example 17 was composed for both hands.

Example 1 was originally meant to form part of Test 1, while Example 17 was originally intended to form part of Test 2. The absence of deviations however meant that these two examples had to be analysed separately from the main study.

The results for total fixations on Example 1 indicate that the amateur sight-readers on average fixated 3.52 times more than the experts. This difference seems rather insignificant, suggesting that both groups fixated with similar frequency on the entire score of Example 1. The results for total fixation duration on the entire score of Example 1 indicate that the amateurs fixated 4.23 seconds longer than the experts. This result once again appears to be insignificant, suggesting no real difference between total viewing time on this score.

Interestingly, the total fixation count results for Example 17 indicate that Group A fixated 41.14 times more on the entire score than Group B. This result appears to be quite significant, suggesting that the expert sight-readers fixated significantly more on Example 17 than the amateurs. The total viewing time results indicate that the experts on average fixated 5.84 seconds longer on the entire score than the amateurs. Unlike the result for fixation count, this difference appears to be less significant, possibly suggesting no real difference in total fixation time on this score.

If the results for both fixation count and duration are combined, it seems that both the experts and amateurs fixated roughly the same amount and duration on the entire score of Example 1. This similar result could perhaps be attributed to the low complexity of the example. The low level of difficulty of the sight-reading test may have required quite elementary sight-reading strategies from the experts (Kopiez & Lee, 2006). The experts may have perceived the low level of complexity while they scanned the music in the four beats introduction and subsequently did not need to use many short fixations to process all the information. Equally, they may not have needed to rely on their chunking ability as highlighted in the research by Wolf (1976). In contrast, the low complexity may have allowed the amateurs to read and perform the exercise with a relatively small number of fixations and fixation time. Their note-by-note reading strategy (Arthur et al., 2016; Fourie, 2004a) may have been adopted and resulted in a relatively low fixation count and duration.

Example 17 however presents a completely different scenario, as the experts seemed to fixate significantly more on the entire score than the amateurs. Interestingly, the fixation duration of both groups on the entire score seems to differ only slightly. This suggests that the experts fixated for the same amount of time but were able to fixate more frequently. This result in turn suggests that the expert sight-readers were able to use more and shorter fixations to perform the example. This result could possibly be due to the increased level of complexity of the example, and perhaps the fact that it was composed using two staves. Expert sight-readers may require more and shorter fixations to process all the aspects of the score when the test is more complex.

In contrast, the amateur sight-readers used fewer and longer fixations on the entire score. The small difference in fixation duration could be accounted for by the amateurs looking down at their hands during the performance. However, this was not enough to make a significant difference in total viewing time. The considerably lower fixation count may suggest that not all aspects of the score were fixated upon. If the performance accuracy for this example is considered however, the amateurs only made 3.5 mistakes out of a possible 48 notes. The combined result indicates that most aspects of the score must have received fixations in order to be processed and performed correctly. The amateurs therefore seem to simply fixate at a slower rate than the experts in this example, resulting in a lower number of fixations. This could perhaps indicate the note-by-note reading strategy highlighted by Fourie (2004b).

In summary, the results for Example 1 suggests that both expert and amateur sight-readers fixated on entire scores with similar frequency and duration. The results for Example 17 suggest that the experts fixated more frequently on the entire score than the amateurs. Both groups however fixated with a similar duration on the entire score. These results will be interrogated further in the discussion of Test 2 results.

5.3.2 Examples 11 and 12

Examples 11 and 12 were both composed for the right hand only. Example 11 was composed in F major and Example 12 in G major. Neither example contained any deviations. These two examples were originally intended to form part of Test 1 but was excluded from the main analysis due to the absence of deviations. Each participant's total number of fixations and total viewing time were recorded for analysis. Each group's total fixations were added together and divided by the number of participants in each group. This provided the researcher with an average fixation count and duration result, which could be compared and discussed.

When the results for both examples are combined, it suggests that the experts on average fixated 13.73 times more on the entire scores as well as 0.01 second longer than the amateurs. Both the fixation count and duration difference seem insignificant, therefore suggesting no real difference between the expert and amateur sight-readers' fixations on the entire scores. The experts rather appear to have been able to use slightly more and shorter fixations than the amateurs. The low complexity of these two examples could perhaps explain the insignificant difference, as both groups probably employed similar reading strategies as in Example 1. The expert sight-readers may have employed elementary sight-reading strategies (Kopiez & Lee, 2006), while the amateurs may have been able to successfully fixate on all aspects in order to facilitate a successful performance.

The results for both fixation count and duration seem to indicate no real difference between the expert and amateur sight-readers' fixations and viewing time on entire scores. Future research could perhaps verify this finding by utilising more examples using these two keys as well as a similar level of complexity.

5.3.3 Test 1

Test 1 consisted of nine examples composed for the right hand only. These examples were composed in various major keys and in several time signatures.

The results for total fixations on entire scores indicate that the amateur sight-readers fixated 3.52 times more across all examples than the experts. This result is statistically insignificant, suggesting no real difference between the groups' total fixations on entire scores.

Similarly, the results for total fixation duration on entire scores indicate that the amateurs fixated 19.05 seconds longer on entire scores than the experts. This result is also statistically not significant, suggestion no real difference between the two groups' total viewing time for the entire scores.

The low complexity of the examples could perhaps account for this minimal difference in fixations on entire scores. Similar reasons could be cited as the ones discussed under Example 1, where expert sight-readers may perceive the low complexity while scanning the music and adapt their sight-reading strategies accordingly. Amateur sight-readers' note-by note reading strategy may have resulted in their relatively low fixation count and duration as there were no highly complex aspects in any of the examples.

In summary, the results indicate no significant difference between the expert and amateur sight-readers' fixations on entire scores. Future research could attempt to verify this result using examples of low complexity composed for one hand only.

5.3.4 Test 2

Test 2 consisted of four examples composed for both hands. The examples were composed in a variety of major keys and in several time signatures. All of the examples contained deviations (accidentals and/or change of time signatures). The examples were also substantially more complex than the examples in Test 1.

The results for fixation count on entire scores for Test 2 indicate that the expert sight-readers fixated 92.76 times more across all examples than the amateurs. This result is statistically significant. The expert sight-readers therefore fixated considerably more on the entire scores than the amateurs in Test 2.

The results for fixation duration on entire scores for Test 2 indicate that the expert sight-readers fixated 22.5 seconds longer across all examples than the amateurs. This finding was however not statistically significant, suggesting no substantial difference between the expert and amateur sight-readers' total viewing time. The slight difference in viewing time could be attributed to the amateurs looking down at their hands in order to plan their motoric performances. The experts on the other hand may have been comfortable with their motoric performances, allowing slightly longer fixation time.

If the fixation count and duration results are combined, the expert sight-readers seem to be able to use significantly more fixations to perform these sight-reading exercises. This suggests that the increased complexity of the sight-reading tests may have altered the experts' sight-reading strategy. When one considers the similar total viewing time of both groups, together with the expert sight-readers' significantly higher fixation count, the conclusion is that the experts' fixations had to be shorter in length. They therefore used more but shorter fixations than the amateurs. The presence of a second stave may have contributed to the increased number of fixations used by the experts, as there was more information (notes and rests) to fixate on and process. This increased complexity may have been perceived while the experts scanned the music during the four-count reading time, resulting in an adjusted sight-reading strategy. The experts clearly had to use more but shorter fixations to cognitively process the information in the sight-reading tests.

In contrast, the amateur sight-readers seemed to use fewer fixations in this test. The minor discrepancy in total viewing time could well be prescribed to the amateurs occasionally glancing down at their hands. Interestingly, in Test 2 the amateurs fixated significantly less frequently on the entire score than the experts. This suggests that while the amateurs looked at the scores for a similar amount of time as the experts, they did not use the same number of fixations. This finding in turn suggests that the few fixations they did focus on the score, must have been longer in duration. The fewer and longer fixations may indeed support the notion suggested by Fourie (2004a) that amateur sight-readers fixate on each note in succession. Their inability to direct more and faster fixations on a score means that they process less information and at a slower rate, suggesting that not all aspects of the score could be processed.

The results for performance accuracy for Test 2 indicate that the amateurs made significantly more errors in their performances. These mistakes could also perhaps account for the difference in fixation count on entire score. The amateurs may not have had the cognitive capacity to fixate on all the aspects (notes) of the scores, leading to the higher error rate. The results indicate that the amateurs on average made 73.66 more mistakes in Test 2 than the experts. It may be safe to assume that at least some of these mistakes were made due to a lack of fixation on some notes, leading to faulty processing and performance. The presence of a second stave may have compounded this issue, as it would be very difficult to fixate on two notes on two staves at the same time. In contrast, the expert sight-readers' higher level of accuracy may be attributed to their increased number of fixations on the score and their ability to utilise horizontal, vertical and diagonal visual movements (Fourie, 2004b).

In summary, the results indicate that the expert sight-readers fixated significantly more on the entire scores in Test 2 than the amateurs. Both groups however fixated for a similar duration on the entire scores. This finding is contrary to the one reported in Test 1, suggesting that increased complexity may alter sight-reading strategies of especially expert sight-readers.

5.4 Key and time signatures

The focus of this study was the cognitive processes involved when reading key and time signatures. The key and time signature aspects of each example was isolated as AOI A for analysis. Each participant's fixations on AOI A was calculated as a percentage of their total fixations on entire scores. The same process was used for fixation duration results. This enabled the researcher to compare and report the percentage of fixations on AOI A between the two groups, as well as with other aspects of the score. The results for key and time signature fixations are discussed in this section, focusing first on Examples 1 and 17, followed by Examples 11 and 12, Test 1 and finally Test 2.

5.4.1 Examples 1 and 17

Examples 1 and 17 were both composed in C major (which means that there were no flats or sharps in the key signature) and in 4/4 time. The performance accuracy results for both these examples indicated that these examples were performed with minimal errors from both groups of participants.

The fixation count results for Example 1 indicate that the amateur sight-readers fixated 0.97% more on AOI A. This difference seems insignificant, suggesting no real difference between the groups' fixations on the key and time signature. Interestingly, 71% of participants did not fixate on the key and time signature at all. This finding may suggest that sight-readers are able to use their peripheral vision to process this particular key and time signature (since there are no sharps or flats to process). Perhaps the instant recognition of the C major key signature also implies a relatively simpler motoric output, as only natural notes are used.

The fixation duration results for Example 1 also indicate that the amateurs fixated 0.86% longer on the key and time signature. The insignificant difference may imply no real difference between length of time spent fixating on AOI A.

The fixation count results for Example 17 indicates that the experts focused 0.09% more frequently on the key and time signatures than the amateurs. The result suggests no significant difference between the groups' fixations on the key and time signature. The fixation duration results indicate the amateurs focused 10% longer on the key and time signature. This difference is slightly more significant than Example 1. If this finding is viewed in light of the amateurs' lower fixation count on entire scores, they may simply have used fewer but longer fixations in order to process and perform the example. The fixations on AOI A may therefore simply have been slightly longer due to the overall sight-reading strategy employed by amateur sight-readers.

In sight-reading Example 17, only 56% of participants fixated on the key and time signature (AOI A). This result was not anticipated when the study was designed. To put this finding into perspective, the two examples with the highest (Example 7) and lowest (Example 11) percentage of participants fixating on AOI A are presented as follows:

- Example 7: 100% of participants fixated on AOI A. This example yielded the highest percentage of participants fixating on AOI A.
- Example 11: 68.5% of participants fixated on AOI A. This example yielded the lowest percentage of participants fixating on AOI A (other than Example 1 and 17).

Example 1 and 17 therefore exhibited a significantly lower percentage of participants who fixated on AOI A.

The high percentage of zero fixations on AOI A in Example 17 could be because C major has a key signature without sharps or flats. It could also be an indication of the participants' perception that C major presents very little challenge to the performance task at hand, and hence requires very little time to process cognitively. Furthermore, the AOI A in Example 1 and 17 included both the key and time signature. If 50% of participants did not fixate on AOI A, then they neglected to fixate on both the key and time signature which appear at the same place in the score. This finding suggests that 4/4 time or common time, when combined with a C major key signature, does not necessarily require fixations to process cognitively. These findings could suggest that sight-readers are able to process C major and 4/4-time signature using their peripheral vision.

In summary, the fixation patterns on the key and time signature of Example 1 and 17 did not differ significantly, suggesting that expert and amateur sight-readers use similar gaze patterns to process the key signature. There were however a substantial number of participants who did not fixate on the key and time signature at all, possibly implying that the C major key signature, coupled with 4/4-time signature, can be processed using peripheral vision.

5.4.2 Examples 11 and 12

The results for Example 11 and 12 are discussed next. Example 11 was composed in G major, while Example 12 was composed in F major. The performance accuracy results indicate relatively low number of errors for both examples, possibly suggesting that the examples were perceived as easy and performed relatively successfully by both groups.

The fixation count results on AOI A indicate that the amateur sight-readers focused 4.53% more fixations on the key and time signature aspects of these two examples than the experts. Similarly, the results also indicate that the amateurs fixated 1.28% longer on the key and time signature aspects of these two examples than the experts. Both these results appear insignificant, suggesting no real difference between the groups' fixations on AOI A. It would seem that both groups fixate with similar frequency and duration on the key and time signatures in these examples of low complexity.

5.4.3 Test 1

The results for fixations on AOI A in Test 1 are discussed next. Test 1 consisted of nine examples composed in various major keys using several time signatures. All of these examples contained deviations (accidentals and/or time signature changes). The performance accuracy results for Test 1 indicated that the amateurs made significantly more errors in their performances than the experts. The total fixation results for entire scores revealed no substantial difference between the experts and amateurs.

The results for fixation count on AOI A reveal that the amateur sight-readers on average fixated 28.02% more frequently on the key and time signature aspects than the experts. This result is statistically not significant, suggesting no real difference between the two groups. Similarly, the fixation duration result indicates that the amateurs on average fixated 19.05% longer on the key and time signature aspects than the experts. Once again, this finding is statistically not significant, suggesting no tangible difference between the two groups.

One can conclude from these results that both expert and amateur sight-readers value key and time signature aspects when performing sight-reading tests, as both groups focus similar number and durations of fixations on these two aspects.

5.4.4 Test 2

The results for fixations on AOI A in Test 2 are discussed next. Test 2 consisted of four examples composed for both hands. The examples were composed in various major keys and in several time signatures. The performance accuracy results indicate that the amateurs made significantly more mistakes in their performances. The total screen fixation results indicate that the experts fixated significantly more on entire scores in Test 2, but both groups fixated for a similar duration on entire scores.

The fixation count results on AOI A suggest that the expert sight-readers on average fixated 2.32% more frequently on the key and time signatures than the amateurs. Similarly, the fixation duration results indicate that the experts on average fixated 1.04% longer on the key and time signatures than the amateurs. Both these results are statistically not significant, suggesting no real difference between the two groups.

One can conclude that both expert and amateur sight-readers value key and time signatures when performing sight-reading tests, as both groups use similar frequency and duration of fixations. Interestingly, this result is the same for examples of both low and high complexity, which suggests that changing complexity does not affect fixations on key and time signatures.

5.5 Deviations

The results for deviations (AOI B) are discussed next. All examples in Test 1 and 2 contained deviations (accidentals and change of time signature). The researcher's initial theory was that these deviations would affect fixation patterns on the actual key and time signature aspects of the scores, which is why deviations were included in the examples. Each participant's fixations on deviations was calculated as a percentage of their total fixations on entire score. The same procedure was followed for fixation duration. The results for Test 1 will be discussed first, followed by Test 2.

5.5.1 Test 1

The results for Test 1 are discussed first. The performance accuracy results indicate that the amateurs made significantly more mistakes than the experts. The results for total fixations on entire scores indicated no significant difference between the groups. Similarly, the fixations on the key and time signatures indicated no noteworthy difference between the groups.

The fixation count results reveal that the amateurs on average focused 10.41% more fixations on the deviations than the experts. Similarly, the fixation duration results indicate that the amateurs on average fixated 21.61% longer on the deviations than the experts. Both these results are statistically not significant, suggesting no pronounced difference between the two groups. This finding submits that both expert and amateur sight-readers fixate with similar frequency and duration on the deviations (accidentals and change of time signatures).

An original theory of this study was that the presence or absence of deviations may affect fixation patterns on the key and time signature aspects. When the results for Test 1 are compared to Examples 11 and 12 (which contained no deviations) however, it appears that the presence or absence of deviations do not affect the fixations on key and time signatures. This is evident because the average fixations on AOI A in Examples 11 and 12 is not significantly lower or higher than the ones in Test 1. There is in fact very little difference between the results on AOI A in these examples. This finding suggests that accidentals and changes of time signature do not necessarily warrant more or less fixations on the key and time signature aspects. This result may in turn suggest that accidentals and changes of time signatures are not seen as related aspects to key and time signatures, but rather processed as part of actual note patterns. Future research could further investigate this finding.

An unanticipated finding in this study was a general lack of fixations on a time signature change at the end of a line. Three of the sight-reading examples (Nos. 5, 9 and 10) included time signature changes as deviations. These changes occurred at the start of either line two or line three of the example. In music score writing, when a time signature change is indicated at the start of a line (other than at the beginning of a piece), the standard practice is to indicate the change of time at the start of the line in question, as well as at the very end of the preceding line. This indication at the end of the preceding line is supposed to act as a cue to give the reader early warning of the change of time signature that is to take effect in the next line.

The use of heat maps illustrates these results:

1. In Example 5 (composed in 4/4 time), a change of time signature at the beginning of the last bar of the second line indicated a 3/4-time change. The start of the third line of the piece indicated a return to 4/4 time. The 4/4-time signature was subsequently indicated at the start of line three and at the end of line two. The time signature indication at the end of line two was labelled AOI 7. Interestingly, only one of out the eighteen participants fixated on this AOI. That is 5.5% of participants. This participant fixated on this time signature change only once. This is significant, if this one fixation is compared to the total fixation count on AOI B by all participants, which was 228. The percentage of fixations directed towards this particular AOI in Example 5 was therefore 0.4%.

The heat maps for Group A (expert) and Group B (amateur) for Example 5 can be seen as **Figures 44** and **45**. These heat maps indicate all the fixations of all participants for each group.

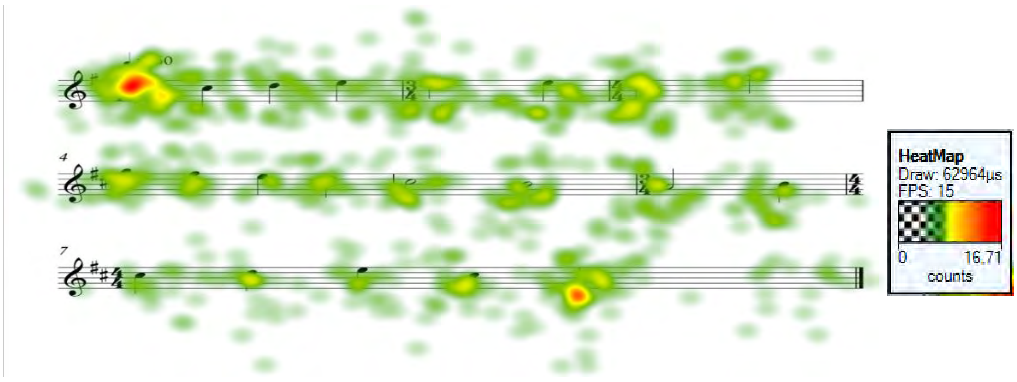


Figure 44: Heat map, Example 5 (Group A expert)

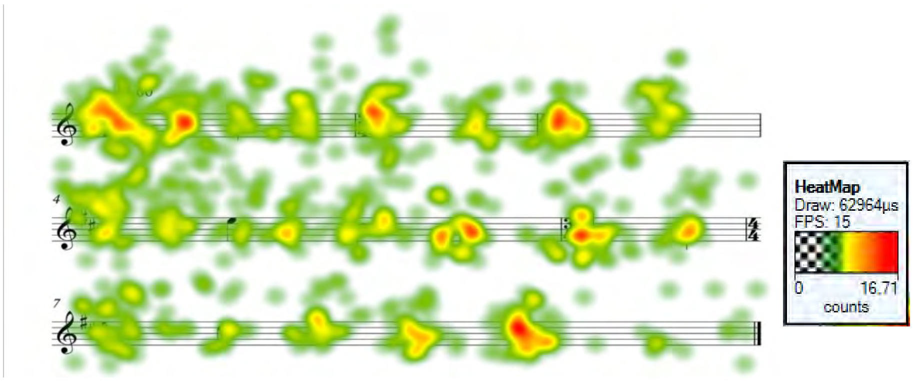


Figure 45: Heat map, Example 5 (Group B amateur)

It is clear from these visual representations that out of eighteen participants in the two groups, only one participant (in Group A expert) fixated on the time signature at the end of line two. This participant could perhaps have fixated on this change of time signature as part of the process of scanning through the line of music. Most of the participants could have ignored this change of time signature, as they were focused on processing the notes. If one reaches the last note of a particular line, it might be instinctual to move one's eyes to the first note of the next line.

2. Example 9: This example was composed in 2/4 time, but a change of time signature was indicated at the start of bar three in the first line. The time returned to 2/4 at the start of the second line, with the cue indicated at the end of line one. This change at the end of line one was marked as AOI 3. While 33% (6 out of 18) of participants fixated on this AOI, their fixation count was still strikingly low. The total fixations on this AOI for all participants was 9 fixations. When compared to the total fixations on AOI B for the example, this AOI received only 3.7% of fixations. The heat maps for both groups for Example 9 are shown as **Figure 46** and **Figure 47**.

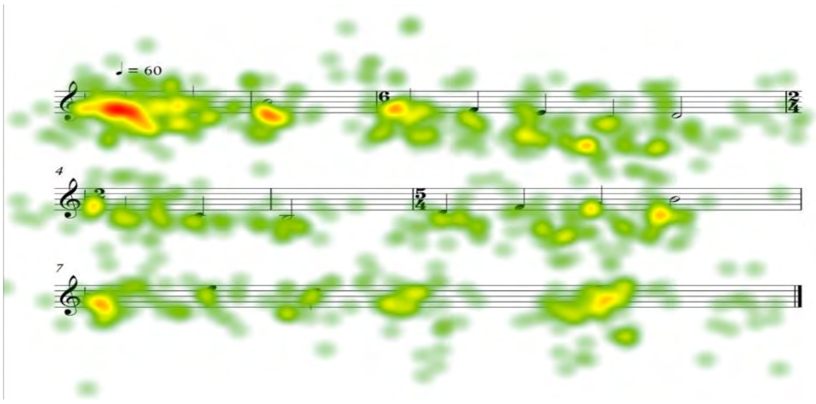


Figure 46: Heat map, Example 9 (Group A expert)

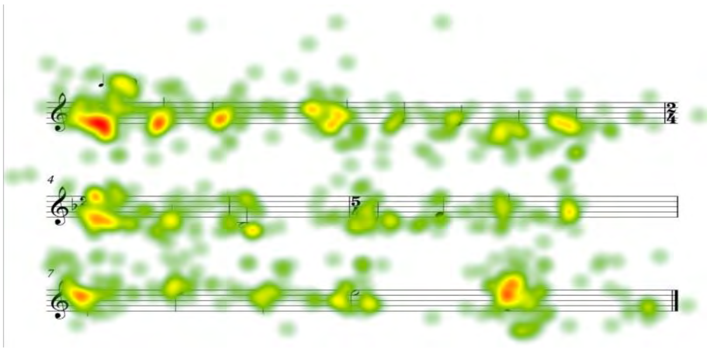


Figure 47: Heat map, Example 9 (Group B amateur)

The heat maps indicate a small number of quick fixations by Group A (expert) on the time signature change at the start of line one of this piece. Group B (amateur) exhibited almost no fixations on this particular aspect in the score.

3. Example 10 also included a similar time signature change. It was composed in 4/4 time but changed to 2/4 time at the start of line two. The change was indicated as a cue at the end of line one. This was marked as AOI 7. For this example, only 5.5% (1 out of 18) of participants fixated on this AOI. The percentage of fixations directed to this AOI compared to the fixations directed to B was 0.2%. The heat maps for both Groups for Example 10 is shown as **Figure 48** and **Figure 49**.

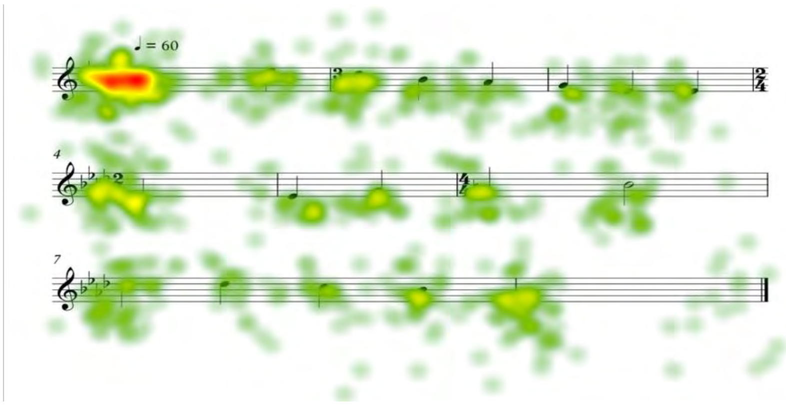


Figure 48: Heat map, Example 10 (Group A expert)

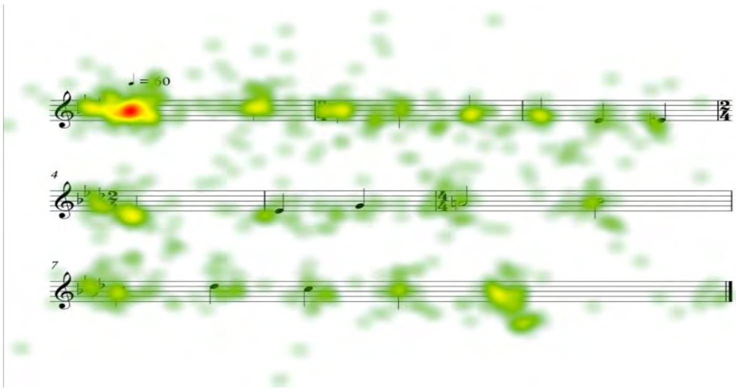


Figure 49: Heat map, Example 10 (Group B amateur)

In this example, Group A (expert) did not fixate at all on the time signature change at the end of line one. Group B (amateur) exhibits one fixation in close vicinity of this aspect.

These results seem to indicate that this type of cue (change of time signature at the end of preceding line) in score writing could be redundant, as most sight-readers did not fixate on this aspect at all. It could be because they simply chose to skip ahead to the next line in order to continue the reading process, anticipating a repeat of the time signature in the next line and therefore not wanting to waste time or continuity. Since this finding was not one of the aims of the study, this feature of score writing was not included in a sufficient number of examples. This change of time signature does not feature at all in the Test 2 examples. It would be interesting to investigate in future if a similar pattern emerges when this time signature change occurs in sight-reading examples of high complexity.

In summary, the results indicate no significant difference between the two groups' fixations on deviations in Test 1. This suggests that both amateur and expert sight-readers recognize deviations and process them with similar fixation patterns. The results also indicate that a time signature change indicated at the end of a line may be a redundant cue.

5.5.2 Test 2

The results for Test 2 are discussed next. The performance accuracy results indicate that the amateurs made significantly more errors in these examples than the experts. The fixation results for entire scores shows that the experts used significantly more fixations than the amateurs to complete these examples. There was however no real difference between the groups' total score viewing time. The results for fixations on key and time signatures also revealed no discernible difference between the two groups' fixation patterns on these two aspects.

The results for fixation count indicate that the amateur sight-readers on average fixated 2.8% more on the deviations than the experts. Similarly, the fixation duration results show that the amateurs on average fixated 1.7% longer on deviations than the experts. Both these results are statistically not significant, suggesting no real difference between the expert and amateur sight-readers' fixation patterns on the deviations.

These findings could mean that both groups are able to identify deviations and use similar fixation patterns to process them. It is interesting to note that the result is the same for both tests, suggesting that complexity does not affect fixation patterns on deviations such as accidentals or change of time signatures.

5.6 Comparison of AOI results

The results for all the AOI are discussed and compared next. The main aim of this study was to investigate the cognitive underpinnings of key and time signatures in music scores. The sub-aims were to compare the fixation patterns of both expert and amateur sight-readers in order to gain insights into the key and time signature aspects. Deviations (accidentals and changes of time signatures) were included to test their effects on the fixations on key and time signatures.

Thus far, the results have indicated that the expert sight-readers were able to perform the examples with greater accuracy (regardless of complexity). The total score fixations results indicated that in simple exercises, both expert and amateur fixate with similar frequency and duration on entire scores. In complex sight-reading exercises however, expert sight-readers use significantly more fixations to perform entire scores than amateurs. Both groups fixated on entire scores for similar duration. The results for key and time signature and deviations indicated no significant difference in fixation patterns on these aspects of the examples, suggesting that expert and amateurs fixate with similar frequency and duration on these aspects.

While these results provide interesting findings regarding different reading strategies of expert and amateur sight-readers, they do not as yet provide much insight into the actual cognitive processes involved when reading key and time signatures. When the results for all AOI are compared to each other however, a different scenario emerges.

If the percentage fixation count and duration on each AOI are compared with each other, it becomes evident that the key and time signature received the highest frequency and duration of fixations. This result is true for both groups and in both tests. The results for AOI A and AOI B are not significant, however this may be as a result of AOI B containing more aspects than AOI A (several examples contained more than one deviation). The results for fixations on AOI A were significantly higher than for the control aspects. Interestingly, these results are true for both the simple and complex sight-reading exercises. This reading may be so much higher, because some participants used regressive fixations (looking back) on this aspect of the score. **Figures 50** and **51** are two randomly selected gaze plots which illustrate this phenomenon. These two gaze plots were selected for their clarity.

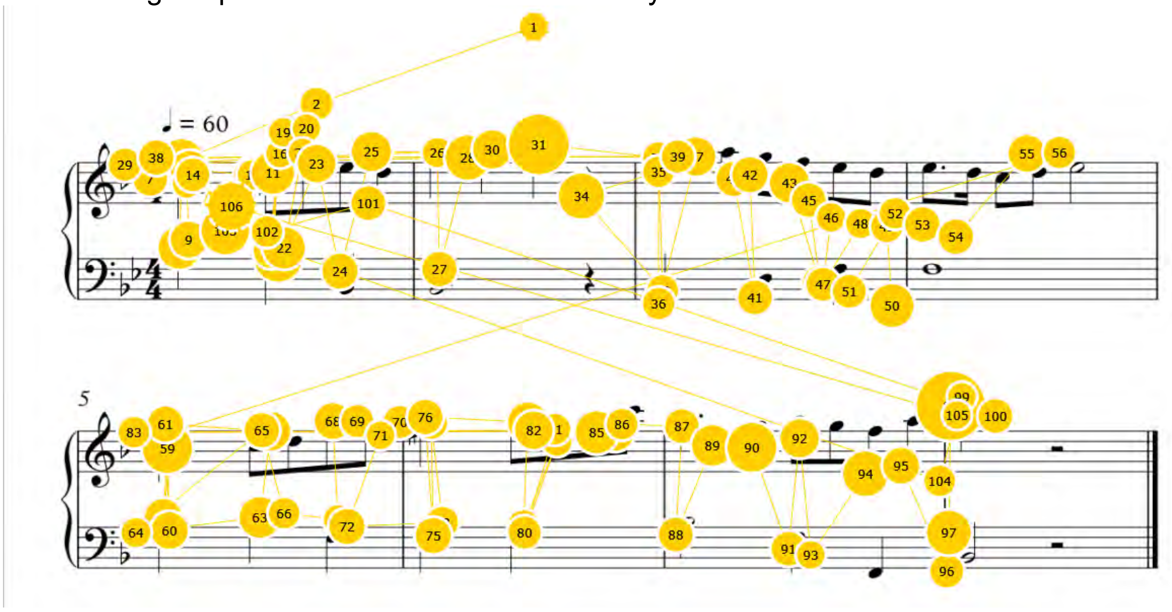


Figure 50: Gaze plot, Example 13 (participant A1)

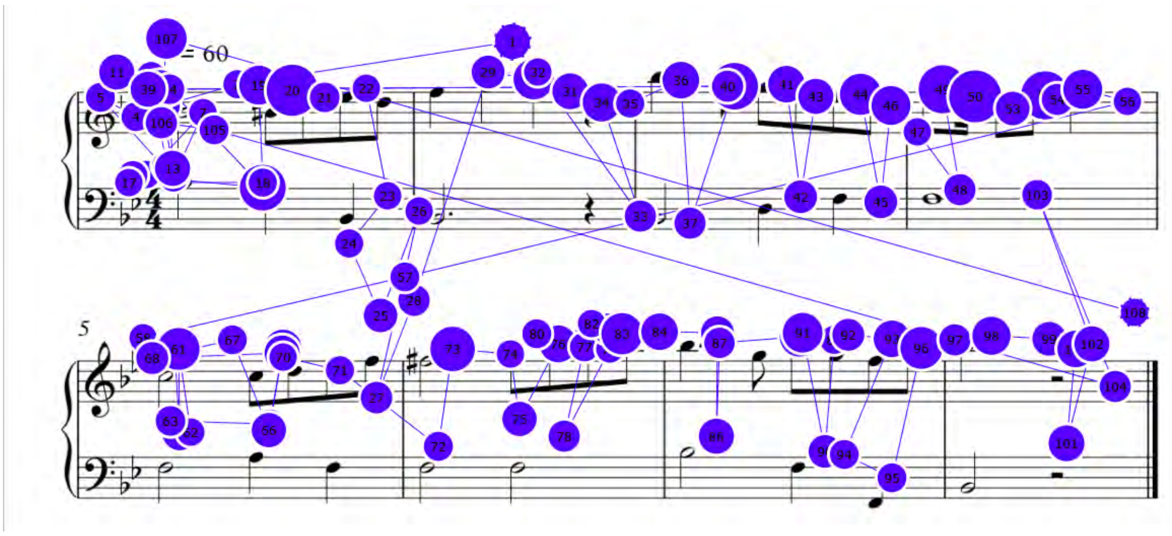


Figure 51: Gaze plot, Example 13 (participant A7)

In both gaze plots, it is clear that these participants looked back at the key and time signature aspect of the score. The key and time signatures contain fixations with numbers ranging from 1 to 107. This suggests that these participants gazed back at AOI A at different stages of the performance.

This finding may suggest several possibilities. If the key and time signature received the highest frequency and duration of fixations, it could suggest that sight-readers do indeed process aspects of music scores in a hierarchical fashion (Cara & Vera, 2016; Kinsler & Carpenter, 1995; Palmer & van der Sande, 1993). This attribute has to date been credited only to expert sight-readers. The results of this study however suggest that amateur sight-readers may also perceive music scores in this manner. Since both expert and amateur sight-readers' key and time signature aspects received the greatest frequency and duration of fixations, it suggests a similarity in cognitive processing of these two aspects. The findings of this study may indeed also suggest that tonality (one of the hierarchical structures in Palmer and van der Sande's (1993) research require more and longer fixations to process cognitively than individual notes.

The high number and duration of fixations on AOI A may also give some insights into the planning phases of the sight-readers' reading processes. If sight-readers spend a significant percentage of their total reading time fixating on the key and time signatures, it may indeed give credit to the notion that tonal and rhythmic awareness is required for successful sight-reading planning and performances (Grutzmacher, 1987; Leonard & House, 1959). If sight-readers are fixating on the very aspects which signify tonality and metre, they may indeed be familiarizing themselves with the required tonality and metre for the exercise. It is interesting to note that as the key signature became more complex, the fixation count and duration on the key and time signature increased. This finding may show that more complex key and time signatures require longer timeframes to comprehend and plan. This finding may in turn suggest that extensive practise in these key signatures as well as improved memory recall of theoretical implications may be vital improve fluency of performances.

The percentage of fixations on the deviations was slightly more and longer than the fixations focused on the control aspect notes. This finding was also true for both expert and amateur sight-readers and was prevalent in both tests. This result may suggest that accidentals and changes of time signatures are perceived and processed with more and longer fixations by both expert and amateur sight-readers. This finding further supports the notion of the hierarchical nature of aspects in music scores (Cara & Vera, 2016; Kinsler & Carpenter, 1995). It also supports the idea posited by Arthur et al. (2016) that sight-readers can detect errors (deviations) in music scores. The finding of this study however suggests that both expert and amateur sight-readers can detect such deviations. The difference in performance accuracy may suggest however that expert sight-readers are more successful at these cognitive processes than amateurs.

5.7 Summary

In this chapter, the results were disseminated and discussed. Several key findings were highlighted and discussed. These include: 1) expert sight-readers are able to perform these examples much more successfully, 2) there is no significant difference between expert and amateur sight-readers' fixation count or duration on entire scores in simple exercises, however expert sight-readers fixate more frequently on entire scores in complex exercises, 3) there is no significant difference between expert and amateur sight-readers' fixation count or duration on key and time signature aspects of scores, 4) there is no significant difference between expert and amateur sight-readers' fixation patterns on deviations, 5) both expert and amateur sight-readers fixate significantly more and for longer on key and time signature aspects of music scores than individual notes (in both simple and complex sight-reading examples). Two unexpected findings were discussed, namely that C major key signature may be processed using peripheral vision, as there exists a considerably low number of fixations on that aspect. Secondly, a time signature indicated at the end of line in music scores may be redundant. Finally, the results indicate that music scores are processed in a hierarchical fashion by both expert and amateur sight-readers, as key and time signatures seem to be deemed especially important in the planning and performance strategy. The same finding is true for deviations in this study.

Chapter 6 – Conclusion

6.1. Introduction

This study aims to explore the fixation patterns of expert and amateur sight-readers focusing on the cognitive underpinnings of reading key and time signatures. Chapter 1 provides an introduction to the study. The background, main aims of the study, key concepts relevant to the research and the research questions were stated. Chapter 2 provides an overview of the current literature relating to eye movements in text and music reading, as well as the current views regarding sight-reading in music education. Chapter 3 outlines the methodological approaches followed in this study. Chapter 4 presents a detailed analysis of the results. Chapter 5 discusses these findings in relation to the literature. Chapter 6 summarises and presents the conclusions of this study. The main research question and the two sub-questions of the research question are addressed systematically in this chapter.

6.2 Addressing the research question

The main research question is: What are the cognitive underpinnings of reading key and time signature aspects in a music score? The two sub-questions of the main research question will be discussed before the main research question is discussed.

6.2.1 How do expert and amateur sight-readers' fixation counts and fixation durations compare when reading key and time signatures?

The findings of this study suggest no link between expertise and fixation patterns on key and time signatures in simple sight-reading exercises. This suggests that experts and amateurs alike fixate on this aspect of sight-reading in simple exercises. The same findings are reported for complex sight-reading exercises.

6.2.2 How do expert and amateur sight-reader's fixation counts and fixation durations compare when reading score deviations (accidentals and changes of time signature)?

The results of this study indicate no significant difference between fixation patterns on deviations in both simple and complex sight-reading exercises.

6.3 Answering the main research question

The main research question for this study is: What are the cognitive underpinnings of reading key and time signature aspects in a music score?

This research proposes that aspects in music scores are processed in a hierarchical fashion. The findings of this study suggest that key and time signatures are deemed especially important when planning and performing sight-reading exercises. The findings indicate that key and time signatures require more and longer fixations to process cognitively. The results of this study also propose that fixations on the key and time signatures imply a number of planning processes involving tonality and metre in order for successful performances to be achieved.

6.4 Limitations of the study

This study provides some insight into the cognitive underpinnings of reading key and time signatures during sight-reading performances. Several limitations became evident during the course of the research process.

Firstly, the research focused solely on pianists performing keyboard sight-reading exercises. This means that the results do not represent sight-reading processes followed by all instrumentalists and vocalists. Further research into a more diverse body of performers is needed to establish whether the results of this study relate specifically to pianists, or whether parallels could be drawn with other kinds of instrumentalist and vocal sight-reading processes.

Secondly, the size of the sample is small (eighteen participants) and taken from a geographically small area. This means that results do not represent generalised findings. The findings need to be explored further with a larger sample from a more widely distributed geographical area. The study also did not consider possible reading disabilities of participants.

Many of the comparative results were statistically insignificant. This means that the sight-reading examples could be better designed, and a greater number given during data collection to improve this aspect. More examples were needed in specific keys to give a better understanding of the effect of complexity of key and time signatures of fixation patterns. Since the results reported for the C major examples (Examples 1 and 17) were unexpected, further research into the findings pertaining to these examples is warranted. The fact that several examples included more than one deviation made the analyses in this study very challenging, as AOI B contained more than one aspect for those examples. A distinct comparison between AOI A, B and C was therefore very difficult to achieve. Future studies could benefit from limiting deviations to a single case per example. This could also help to separate key and time signature deviations. Such a separation would make individual analyses for key and time signatures possible as the data for both variables could be separated during analysis.

This study could also not effectively study the eye-hand span and its effect on the aspects in question. This was mainly due to technological shortfalls. Furthermore, recording equipment could not be utilised, resulting in time consuming methods of performance assessment. Future studies would benefit from ensuring that the slide transitions are automatic, as this would eliminate the manual cutting of performance times. This aspect of data collection was unknown to the researcher during data collection.

The sight-reading examples in Test 2 (composed for two hands) could be greater in number. There were only four included in this study. These examples also did not feature a change of time signature at the end of a line (as was the case in Test 1). Future research could utilise complex sight-reading examples including this particular aspect to further test its effect on fixation patterns.

A critical evaluation of this study is outlined in **Table 11.**

Table 11: Critical evaluation of the study

Discussion area	Strengths of this study	Weaknesses of this study
Design		
Non-experimental quantitative design	• The aim of this study was to compare the fixation patterns of expert and amateur sight-readers. The chosen research design allows for the exploration and comparison of relationships (McMillan & Schumacher, 2010). This aspect made the chosen research design suitable for this study. • Reliability was ensured with the use of an independent and objective measurement tool. • Statistical power was increased with the use of a standardised protocol.	• Statistical power was decreased by the small sample size.
Participants		

Two groups of participants were used in this study. These were experienced and amateur sight-readers.	• Participants from similar geographical areas were used. • Participants also held similar practical qualifications (minimum of Grade 6).	• The study could not draw on a sample of participants with similar years of experience. The average experience of Group A was much higher than Group B. Future research could attempt to use a sample of similar experience. • Not all participants who initially responded to participate in this study completed the data collection. • The participants all came from a smallish geographical area. This could negatively impact the generalisation of results.
Data Collection		
A Tobii X2-60 Hz eye-tracker was used for data collection.	• The measurement tool was effective and recorded data for all participants. • Limited verbal instructions were necessary during the calibration process. • All participants were able to complete the calibration process with adequate accuracy.	• The data collection method was unable to ensure that every participant looked at the screen for the same amount of time. The rest slide always received four metronome beats, after which the Tobii specialist pressed the spacebar on the computer keyboard to switch to the next slide. If there was a split-second delay in this switching-over process, the new slide might not appear exactly on the next metronome count. The researcher always started counting four beats once the new slide appeared (using the metronome counts). Some participants could theoretically have looked at the scores for milliseconds longer than others. This simply made comparisons of total performance times impossible. Several participant's data had to be discarded for this reason.
Results		
Results were presented with graphs and tables.	• Group scores for each example were presented clearly. • The differences between the two groups were presented clearly. • Inferential statistics tested the difference between the two groups and was able to conclude results for both Test 1 and 2 for all variables.	• Setting examples for this study was a challenge. The examples in Test 1 were too easy for the expert sight-readers, while the examples in Test 2 were too difficult for the novices. Future studies could perhaps focus on only one of these levels of complexities. • The study could also not effectively describe the difference between fixation patterns on key and time signature aspects in musical score. It could only account for fixation patterns on both aspects. This discovery was only made late into the research process. Future research could use more examples testing each variable in isolation to come to more finite conclusions.

6.5 Recommendations for future research

Future research could investigate the general lack of fixations on time signature deviations at the end of a line of music. This finding was not anticipated in this study, which means that this aspect was not included in enough instances in sight-reading exercises to truly verify the results. This deviation was also absent in the sight-reading examples composed for two hands.

This study grouped key and time signature aspects (as well as accidentals and changes of time signature) under one category of data. Future research could further separate these two categories to investigate the difference in cognitive underpinnings of these aspects separately. It would be interesting to investigate whether key and time signatures, and their deviations in the score, lead to similar fixation patterns from sight-readers. This would be possible if the sight-reading examples are designed to include only one deviation. A researcher could then more easily compare fixation patterns on the key and time signature aspect, one deviation (accidental or change of time signature) and one control. Such findings may provide more insight into the cognitive processes involved when sight-reading accidentals and changes of time signatures in music scores. Indeed, when studying specific aspects of music scores, it may be helpful to limit the participant sample to expert sight-readers only, as they may perform more accurately and thus provide clearer visual patterns for analysis. The amateur sight-readers in this study coped well with the simple sight-reading tests, but struggled to manage performances for the complex tests. This phenomenon was less prevalent in the expert sight-reader group.

The findings of this study only represent sight-reading strategies of pianists. Future research could apply the methodological approaches of this study to other instrumentalists or vocalists to investigate whether the cognitive underpinnings are the same or different.

The results for the examples in C major could be explored further in future research. Research could further investigate the use of peripheral vision when responding to this key signature. The results could also be investigated using other instruments, to explore whether these results are unique to the piano only. Similar studies could be conducted using F and G major key signatures.

Studies can also investigate the effect of the deviations used in this study on the eye-hand span of sight-readers. It would be most interesting to see whether these deviations also extend the eye-hand span, as was reported in a study using different deviations (Huovinen et al. 2018).

Test 2 only included a few examples (four in total). Future research could investigate the cognitive underpinnings of reading key and time signatures of complex sight-reading exercises with a larger pool of stimuli. Using complex examples as testing stimuli may be beneficial for future research, as the differences between the two groups became marked in the complex tests. If complex examples are used in future research, it may be helpful to limit the sample to expert sight-readers only.

Future research is needed to investigate the implications of this study on music education. The results of this study, combined with numerous others with similar methodologies, could be disseminated and key areas for sight-reading development identified. These key areas could then become the focus of educational research, aimed at designing effective strategies to improve sight-reading skills.

6.6 Conclusions

The findings of this study contribute quantitative data to the general body of knowledge in the field of music cognition, linking eye movements and cognitive behaviour during sight-reading performances. The findings seem to suggest that music notation is cognitively processed in a hierarchical fashion, with key and time signatures a specific focus of the sight-reader's attention. Key and time signatures require more and longer fixations to process than other aspects of music scores. Similarly, deviations (accidentals and change of time signatures) also require more and longer fixations than notes which belong to the tonality of the exercise. Interestingly, the findings are true for both expert and amateur sight-readers. The expert sight-readers appeared to be more successful at these cognitive processes than the amateurs. By implication, sight-reading is thus a learned skill which can be taught to any musician.

The research suggests that amateurs tend to use a note-by-note reading approach, which often results in unsuccessful (slow or inaccurate) performances. This is evident in their fewer but longer fixations used to process music scores. In piano sight-reading specifically, this approach is problematic, as there are numerous aspects of the score that must be processed simultaneously in order to read effectively within a specific timeframe.

These findings in turn may suggest that sound theoretical knowledge of key and time signatures is needed to perform sight-reading exercises of high complexity. The hierarchical structures used by sight-readers are not identified through talent or luck, but rather constructed with the aid of inherent theoretical and aural knowledge. Expertise in these theoretical concepts may improve efficiency in sight-reading performances.

Through an awareness of the extent that theory and aural informs hierarchically organizing, processing and application, music educators might foster a more musically integrated approach to the development of sight-reading skills. Just as in text reading where educators do not expect learners to read fluently without using carefully constructed building blocks in the learning process, so too should music educators employ educational models that foster key building blocks (like theoretical and aural knowledge of key and time signatures) to develop expert sight-reading skills.

Bibliography

ABRSM, 2019. ABRSM. [Online]
Available at: https://us.abrsm.org/en/our-exams/what-is-a-graded-music-exam/sight-reading/
[Accessed 13 April 2020].
Altenmüller, E. O., 2001. How many music centers are in the brain?. In: R. J. Zatorre & I. Peretz, eds. The Biological Foundations of Music. New York: New York Academy of Sciences, pp. 27 - 280.
American Psychological Association, 2010. Publication of the American Psychological Association. 6th ed. Washington DC: American Psychological Association.
Arthur, P., Khuu, S. & Blom, D., 2016. Music sight-reading expertise, visually disrupted score and eye movements. Journal of Eye Movement Research, 9(7), pp. 1 - 12.
Babbie, E., 2008. The Basics of Social Research. 4th ed. Boston: Thomson Wadsworth.
Balota, D. A., Pollatsek, A. & Rayner, K., 1985. The interaction of contextual contraints and parafoveal visual information in reading. Cognitive Psychology, 17, pp. 364 - 390.
Betts, S. L. & Cassidy, J. W., 2000. Development of sight-reading and harmonization skills among university class piano students. Journal of Research in Music Education, 48(2), pp. 151 - 161.
Brodsky, W. et al., 2008. The mental representation of music notation, notational audiation. Journal of Experimental Psychology: Human Perception and Performance, 34(2), pp. 427 - 445.
Cara, M. A. & Vera, G. G., 2016. Silent reading of music and texts; Eye movements and integrative reading mechanisms. Journal of Eye Movement Research, 9(7), pp. 1 - 17.
Carey, D. A., 1959. A survey of the sight reading ability of senior students in nine Kansas high schools. Kansas: University of Kansas.
Drai-Zerbib, V. & Baccino, T., 2005. Expertise in reading music: Intermodal integration. L'Annee Psychologique, 105, pp. 387 - 422.
Drai-Zerbib, V., Baccino, T. & Bigand, E., 2011. Sight reading expertise: Cross-modality integration investigated using eye tracking. Psychology of Music, 40(2), pp. 216 - 235.
Elliott, C. A., 1982. The relationships among instrumentalist sight-reading ability and seven selected predictor variables. Journal of Research in Music Education, 30(1), pp. 5 - 14.
Fink, L. K., Lange, E. B. & Groner, R., 2019. The application of eye-tracking in music research. Journal of Eye Movement Research, 11, pp. 1 - 4.
Fourie, E., 2004a. The influence of visual interference on eye-hand span. Musicus, 32(2), pp. 85 - 88.
Fourie, E., 2004b. The processing of music notation: some implications for piano sight-reading. Journal of Musical Arts in Africa, 1(1), pp. 1 - 23.
Furneaux, S. & Land, M. F., 1999. The effects of skill on the eye-hand span during sight-reading. Proceedings of the Royal Society B: Biological Sciences, 266, pp. 2435 - 2440.
Gilman, E. & Underwood, G., 2003. Restricting the field of view to investigate the perceptual spans of pianists. Visual Cognition, 10, pp. 201 - 232.
Goolsby, T. W., 1994a. Eye movement in music reading: Effects of reading ability, notational complexity, and encounters. Music Perception, 12, pp. 77 - 96.
Goolsby, T. W., 1994b. Profiles of processing: Eye movements during sightreading. Music Perception, 12, pp. 97 - 123.
Goolsby, T. W., 1994. Profiles of Processing: Eye movements during sightreading. Musical Perception: An Interdisciplinary Journal, 12(1), pp. 97 - 123.
Gordon, E. E., 2012. Learning Sequences in Music: A Contemporary Music Learning Theory. Chicago: GIA Publications.
Gravetter, F. J. & Forzano, L. B., 2011. Research Methods for the Behavioral Sciences. 4th ed. s.l.:Cengage Learning.
Gruhn, W. et al., 2006. Supressing reflexive behaviour: saccadic eye movements in musicians and non-musicians. Musicae Scientiae, 10(1), pp. 19 - 32.

Grutzmacher, P. A., 1987. The effect of tonal **pattern** training on the aural perception, reading recognition, and melodic sight-reading achievement of first-year instrumental music students. Journal of Research in Music Education, 35(3), pp. 171 - 181.
Hallam, S., 2001. The development of expertise in young musicians: Strategy use, knowledge acquisition and individual diversity. Music Education Research, 3, pp. 7 - 23.
Hayhoe, M. & Ballard, D., 2005. Eye movements in natural behaviour. Trends in Cognitive Sciences, 9(4), pp. 189 - 194.
Hébert, S. et al., 2008. A case study of music and text dyslexia. Music Perception: Special issue on musical difficulties and disorders, 25, pp. 369 - 381.
Hébert, S. & Cuddy, L. L., 2006. Music-reading deficiencies and the brain. Advances in Experimental Psychology: Special issue on music performance, 2, pp. 199 - 206.
Hicks, C. E., 1980. Sound before sight: Strategies for teaching sight reading. Music Educators Journal, 66(8), pp. 53 - 55.
Hoffner, C. R., 1969. Teaching music in the secondary schools. Belmont: Wadsworth.
Holmqvist, K. et al., 2015. Eye tracking: A comprehensive guide to methods and measures. Oxford: Oxford University Press.
Houlahan, M. & Tacka, P., 2008. Kodaly Today: A cognitive approach to elementary music education. New York: Oxford University Press.
Huovinen, E., Ylitalo, A.-K. & Puurtinen, M., 2018. Early attraction in temporally controlled sight reading in music. Journal of Eye Movement Research, 11(2), pp. 1 - 30.
Jacobsen, O. I., 1928. An experimental study of photographing eye-movements in reading music. Music Supervisors' Journal, 14, p. 63 + 65 + 67 + 69.
Jarodzka, H., Holmqvist, K. & Gruber, H., 2017. Eye tracking in educational science: Theoretical frameworks and research agendas. Journal of Eye Movement Research, 10(3), pp. 1 - 18.
Karatekin, C., 2007. Eye tracking technology of normative and atypical development. Developmental Review, 27(3), pp. 283 - 348.
Killian, J. N., 1991. The relationship between sightsinging accuracy and error detection in junior high singers. Journal of Research in Music Education, 39, pp. 216 - 224.
Kinsler, V. & Carpenter, R. H., 1995. Saccadic eye movements while reading music. Vision Research, 35, pp. 1447 - 1458.
Kopiez, R. & Lee, J. I., 2006. Towards a dynamic model of skills involved in sight reading music. Music Education Research, 8(1), pp. 97 - 120.
Kopiez, R. & Lee, J. I., 2008. Towards a general model of skills involved in sight reading music. Music Education Research, 10(1), pp. 41 - 62.
Kostka, M., 1997. Effects of self-assessment and successive approximations on "knowing" and "valuing" selected keyboard skills. Journal of Research in Music Education, 45, pp. 273 - 281.
Kostka, M. J., 2000. The effects of error-detection practice on keyboard sight-reading achievement of undergraduate music majors. Journal of Research in Music Education, 48(2), pp. 114 - 122.
Last, J., 1972. The Young Pianist: An approach for teachers and students. 8th ed. New York: Oxford University Press.
Leonard, C. & House, R., 1959. Foundations of Principles of Music Education. New York: McGraw-Hill Book Co.
Liperote, K. A., 2006. Audiation for beginner instrumentalists: Listen, speak, read, write. Music Educators Journal, 93(1), pp. 46 - 52.
London, T. C., 2011. Sound at Sight: 2nd series: Sight reading for Piano, Grade 5 and 6, Book 3. London: Trinity College London.
Lowder, J., 1983. Evaluation of keyboard skills required in college class piano programs. Contributions to Music Education, 10, pp. 33 - 38.
Madell, J. & Hébert, S., 2008. Eye movements and music reading: Where do we look next. Music Perception, 26(2), pp. 157 - 170.
Mainwaring, J., 1951. Psychological factors in **t**he teaching of music. British Journal of Educational Psychology, 21, pp. 199 - 213.

Mavlov, L., 1980. Amusia due to rhythm agnosia in a musician with left hemisphere damage: a non-auditory supramodel defect. Cortex, 16, pp. 331 - 338.
McConkie, G. W. & Rayner, K., 1975. The span of the effective stimulus during a fixation in reading. Perception and Psychophysics, 17, pp. 578 - 586.
McMillan, J. H. & Schumacher, S., 2010. Research in Education. 7th ed. New Jersey: Pearson Education.
McPherson, G. E., 1994. Factors and abilities influencing sightreading skill in music. Journal of Research in Music Education, 42(3), pp. 217 - 231.
Mishra, J., 2014. Factors related to sight-reading accuracy: A meta-analysis. Journal of Research in Music Education, 61(4), pp. 452 - 465.
O'Dwyer, L. M. & Bernauer, J. A., 2014. Quantitative Research for the Qualitative Researcher. London: Sage.
Osborne, M. E., Wright, M. E., Adams, G. W., Ranucci, E. R., Garofalo, R. J. Wagstaff, J. A., Swanzy, D., McLean, J., Leong, P. M. & Kugler, A. M. 1976. The idea bank: Teaching sight-reading. Music Educators Journal, 62(7), pp. 62 - 69.
Palmer, C., van de Sande, C. 1993. Units of Knowledge in Music Performance. Journal of Experimental Psychology: Learning, Memory, and Cognition, 19(2), pp. 457 – 470.
Palmer, C., van de Sande, C. 1995. Range of Planning in Music Performance. Journal of Experimental Psychology: Human Perception and Performance, 21(5), pp. 947 – 962.
Palmer, C., Pfordresher, P.Q. 2003. Incremental Planning in Sequence Production. Psychological Review, 10(4), pp. 683 – 712.
Pascual-Leone, A., 2001. The brain that plays music and is changed by it. In: R. J. Zatorre & I. Peretz, eds. The Biological Foundations of Music. New York: New York Academy of Sciences, pp. 315 - 329.
Penttinen, M. & Huovinen, E., 2011. The early development of sight-reading skills in adulthood: A study of eye movements. Journal of Research in Music Education, 59(2), pp. 196 - 220.
Petzold, R. G., 1960. The perception of music symbols in music reading by normal children and children gifted musically. Journal of Research in Music Education, 28, p. 271.
Phillips, M. J., 2013. Middle school junior high music: Making sight-reading fun: Ten ideas for success. The Choral Journal, 53(7), pp. 59 - 63.
Polanka, M., 1995. Research note: Factors affecting eye movements during the reading of short melodies. Psychology of Music, 23, pp. 177 - 183.
Puurtinen, M., 2018a. Eye on the music reading: A methodological review of studies from 1994 to 2017. Journal of Eye Movement Research, 11(2), pp. 1 - 16.
Puurtinen, M., 2018b. Learning on the job: Rethinks and realizations about eye tracking in music-reading studies. Frontline Learning Research, 6(3), pp. 148 - 161.
Rayner, K., 1998. Eye movements in reading and information. Psychological Bulletin, Volume 124, pp. 372 - 422.
Rayner, K., Warren, T., Juhasz, B. J. & Frazier, L., 2006. Immediate disambiguation of lexically ambiguous words during reading: Evidence from eye movements. British Journal of Psychology, 97, pp. 467 - 482.
Roseman, S., Altenmuller, E. & Fahle, M., 2016. The art of sight-reading: Influence of practice, playing tempo, complexity and cognitive skills on the eye-hand span in pianists. Psychology of Music, 44(4), pp. 658 - 673.
Roux, F.-E.et al., 2007. When <<Abegg>> is read and (<<A,B,E,G,G>>) is not; A cortical stimulation study of musical score reading. Journal of Neurosurgery, 106, pp. 1017 - 1027.
Salis, D. L., 1977. The Identification and Assessment of Cognitive Variables Associated with Reading of Advanced Music at the Piano (Doctoral Dissertation, University of Pittsburgh, Pennsylvania). Dissertation Abstracts International, Volume 38.
Saxon, K., 2009. The science of sight reading. American Music Teacher, 58(6), pp. 22 - 25.
Sergent, J., Zuck, E., Terriah, S. & MacDonald, B., 1992. Distributed neural network underlying musical sight-reading and keyboard performance. Science, 257, pp. 106 - 109.
Siebenhaler, D. J., 1997. Analysis of teacher-student interactions in the piano lessons of adults and children. Journal of Research in Music Education, 45, pp. 6 - 20.

Slattery, T. J., Pollatsek, A. & Rayner, K., 2006. The time course of phonological and orthographic processing of acronyms in reading: Evidence from eye movements. Psychonomic Bulletin and Review, 13, pp. 412 - 417.
Sloboda, J. A., 1974. The eye-hand span: An approach to the study of sight reading. Psychology of Music, 2, pp. 4 - 10.
Sloboda, J. A., 1977a. Phrase units as determinants of visual processing in music reading. British Journal of Psychology, Volume 68, pp. 117 -124.
Sloboda, J. A., 1977b. The psychology of music reading. Psychology of Music, 6, pp. 3 - 20.
Sloboda, J. A., 1984. Experimental studies of music reading: A review. Music Perception: An Interdisciplinary Journal, 2(2), pp. 222 - 236.
Steward, L. & Walsh, V., 2000. Neuropsychology: Music of the hemispheres. Current Biology, 11(4), p. R125 R127.
Suzuki, S., 1983. Nurtured by Love: The classic approach to talent education. USA: Alfred Publishing Co., Inc.
Thomas, R., 1966. A study of new concepts, procedures and achievements in music learning as developed in selected music education programmes, Washington DC: Department of Health, Education and Welfare, Bureau of Research.
Thompson, S. & Lehmann, A. C., 2004. Strategies for sight-reading and improvising music. In: A. Williamon, ed. Musical Excellence: Strategies and Techniques to enhance performance. New York: Oxford University Press, pp. 143 - 159.
Thyer, B. A., 2010. The Handbook of Social Work Research Methods. 2nd ed. London: Sage.
Tobii, 2010a. Tobii Product Description. [Online]
Available at: tobiipro.com/siteassets/tobii-pro/product-descriptions/tobii-pro-x3-120-product-description.pdf/?v+1.0.7
[Accessed 22 September 2019].
Tobii, 2010b. www.tobiipro.com. [Online]
Available at: https://www.tobiipro.com/siteassets/tobii-pro/learn-and-support/design/eye-tracker-timing-performance/tobii-eye-tracking-timing.pdf?v=1.0
[Accessed 22 August 2019].
Tobii, T., 2010c. Tobii Technology. [Online]
Available at: www.tobiipro.com/siteassets/tobii-pro/learn-and-support/design/eye-tracker/timing/performance/tobii-eye-tracking-timing.pdf/?v=1.0
[Accessed 22 January 2019].
Trantham, W. E., 1970. A music theory approach to beginning piano instruction for the college music major. Journal of Research in Music Education, 18, pp. 49 - 56.
Trinity College London, 2017. Piano Syllabus Piano/Piano Accompanying. London: Trinity College London.
Truitt, F. E., Clifton, C., Pollatsek, A. & Rayner, K., 1997. The perceptual span and the eye-hand span in sight reading music. Visual Cognition, Volume 4, pp. 146 - 161.
Unisa, 2016. UNISA. [Online]
Available at: https://www.unisa.ac.za/sites/corporate/default/About/What-we-do/Arts-&-culture/Directorate-Music/Syllabi
[Accessed 11 May 2020].
Van Zyl, S., 2018. Audiation, aural training and the visually impaired pianist in South Africa. Journal of Musical Arts in Africa, 15(1 - 2), pp. 119 - 130.
Waters, A. J. & Underwood, G., 1998. Eye movements in a simple music reading task: A study of expert and novice musicians. Psychology of Music, 26, pp. 46 - 60.
Weaver, H. E. & Nuys, K. V., 1943. Studies in ocular behavior in music reading. Psychological Monographs, pp. 1 - 50.
Wheeler, L. R. & Wheeler, V. D., 1952. The relationship between music reading and language reading abilities. Journal of Educational Research, 45(6), pp. 439 - 450.
Wilkinson, K. M. & Mitchell, T., 2014. Eye tracking research to answer questions about augmentative and communication research and intervention. Augmentative and Alternative Communication, 20(2), pp. 106 - 119.

Wilming, N. et al., 2017. Data Descriptor: An extensive dataset of eye movements during viewing of complext images. Scientific Data, 31 January, pp. 1 - 11.
Wolf, T., 1976. A cognitive model of musical sight reading. Journal of Psycholinguistic Research, 5, pp. 146 - 171.

INVITATION TO PARTICIPANTS (Appendix A)

Dear fellow musician

Re: Invitation to participate in a research study

You are invited to participate in a research study entitled "Gaze patterns of skilled and unskilled sight readers focussing on the cognitive processes involved in reading key and time signatures". Your participation is important to assist forming greater understanding of the cognitive underpinnings of sight reading.

The research will be undertaken through an eye tracker study. Your participation in the research is anonymous and your identity will not be revealed. The collection of this data will require roughly thirty minutes of your time.

If you agree to participate, I will explain in more detail what will be expected of you, and provide you with the information you need to understand the research. These guidelines would include potential risks, benefits, what the research will be used for and your rights as a participant. Once this study has been approved by the Rhodes University Ethical Standards Committee, you will be sent the letter of ethical approval. If you wish to complain about the way the research is being carried out, you are welcome to contact the Rhodes University Ethical Standards by emailing Siyanda Manqele at s.manqele@ru.a.c.za.

Participation in this research is voluntary and a positive response to this letter of invitation does not oblige you to take part in this research. To participate, you will be asked to sign a consent form to confirm that you understand and agree to the conditions, prior to any eye tracker study commencing. Please note that you have the right to withdraw at any given time during the study.

Thank you for your time and I hope that you will respond favourably to our request.

Yours sincerely,

____

J.F. Viljoen

____

Supervisor: Prof. Catherine Foxcroft

Biographical Questionnaire (Appendix B)

1. First name:

___

2. Surname:

___

3. Age:

___

4. Is the piano your first instrument?

   Yes

   No

5. How many years have you been playing the piano?

___

6. Do you consider yourself a good sight-reader?

   Yes

   No

   Maybe

RHODES UNIVERSITY
Where leaders learn

Appendix C

INFORMED CONSENT DECLARATION

(Participant)

Project Title: Gaze patterns of skilled and unskilled sight readers focussing on the cognitive processes involved in reading key and time signatures.

J.F. Viljoen from the Department of Music and Musicology, Rhodes University has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to study sight reading skills.

2. The Rhodes University has given ethical clearance to this research project and I have seen/ may request to see the clearance certificate.

3. By participating in this research project I will be contributing towards the understanding of the cognitive processes involved during sight reading. This could help further research develop strategies to help learners learn how to sight read efficiently.

4. I will participate in the project by performing one standardized Trinity College London sight reading exercise and a further 14 sight reading examples composed for this study.

5. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

6. I will not be compensated for participating in the research, but my out-of-pocket expenses will be reimbursed.

7. There may be risks associated with my participation in the project. I am aware that

   a. the following risks are associated with my participation: embarrassment caused by possible performance mistakes.

RHODES UNIVERSITY
Where leaders learn

b. the following steps have been taken to prevent the risks: the sight reading examples composed for the study are written so that they could be performed by all participants. Accuracy in performance is not required.
c. there is a 50% chance of the risk materialising

8. The researcher intends publishing the research results in the form of a thesis. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.

9. I will not receive feedback regarding the results obtained during the study. Should you at any time wish to know the results, you are free to contact the researcher and results will be disclosed to you via email.

10. Any further questions that I might have concerning the research or my participation will be answered by J.F. Viljoen at jfviljoen88@gmail.com.

11. By signing this informed consent declaration I am not waiving any legal claims, rights or remedies.

12. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

13. Request to take pictures, video and voice recording for this study

I, ………………………………………………………………………….. have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

…………………………………..	…………………………	…………………………
Participants signature	**Witness**	**Date**

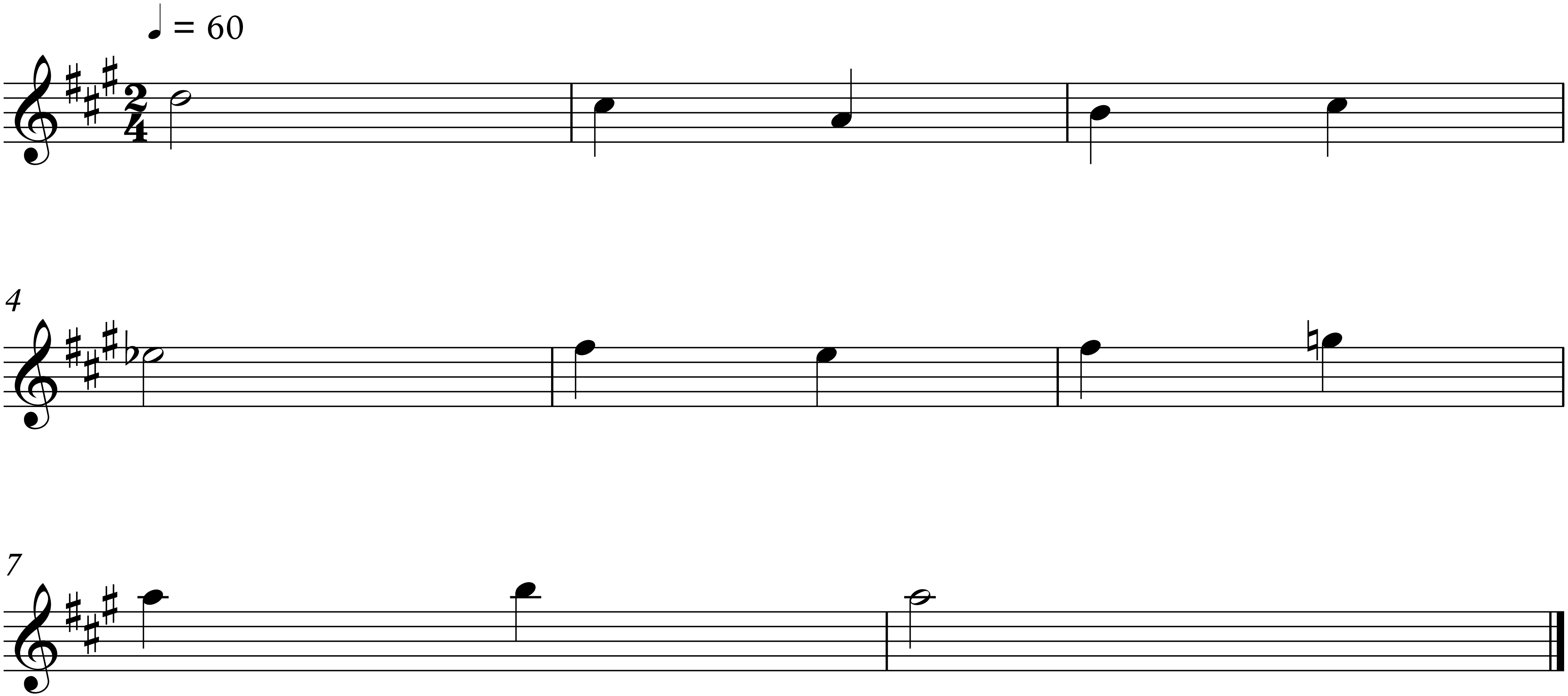
Appendix D

Appendix E 1

Appendix E 2

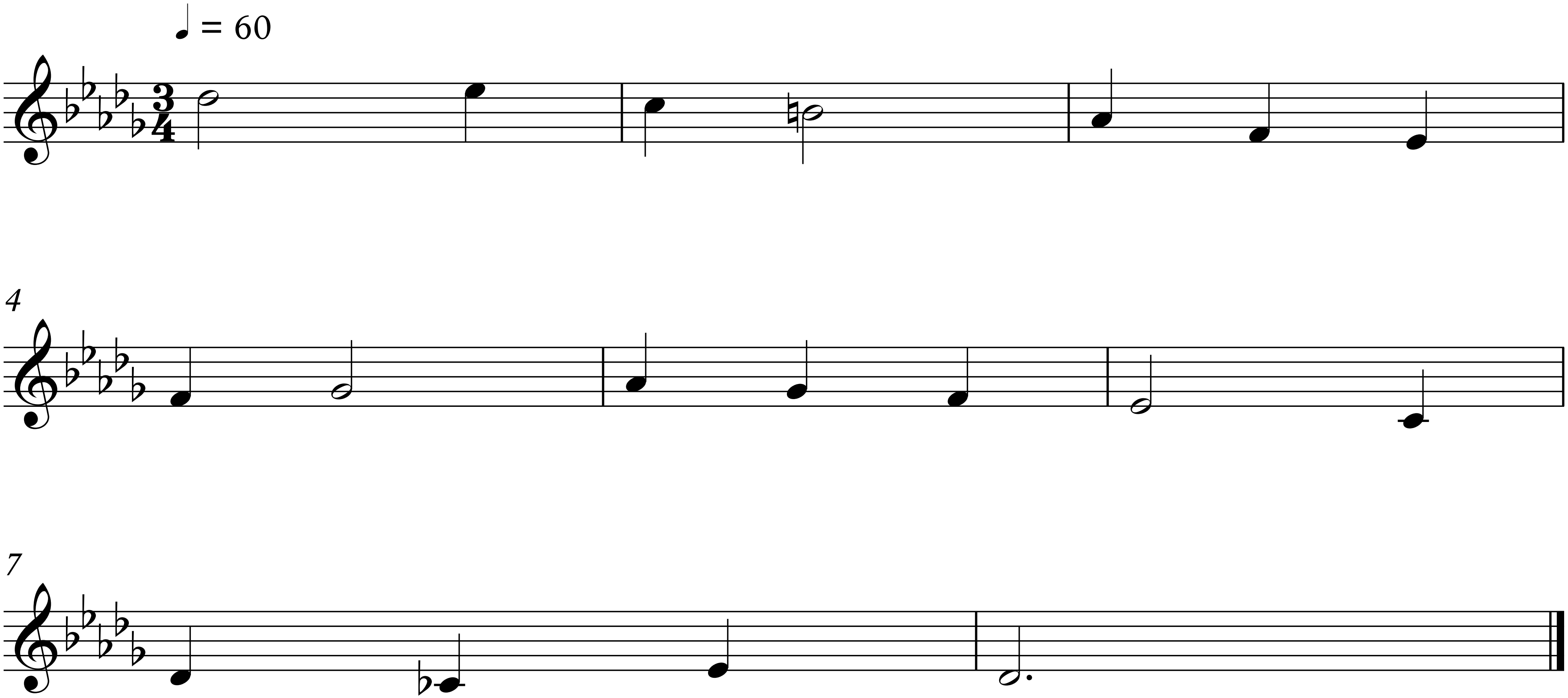
Appendix E 3

Appendix E 4



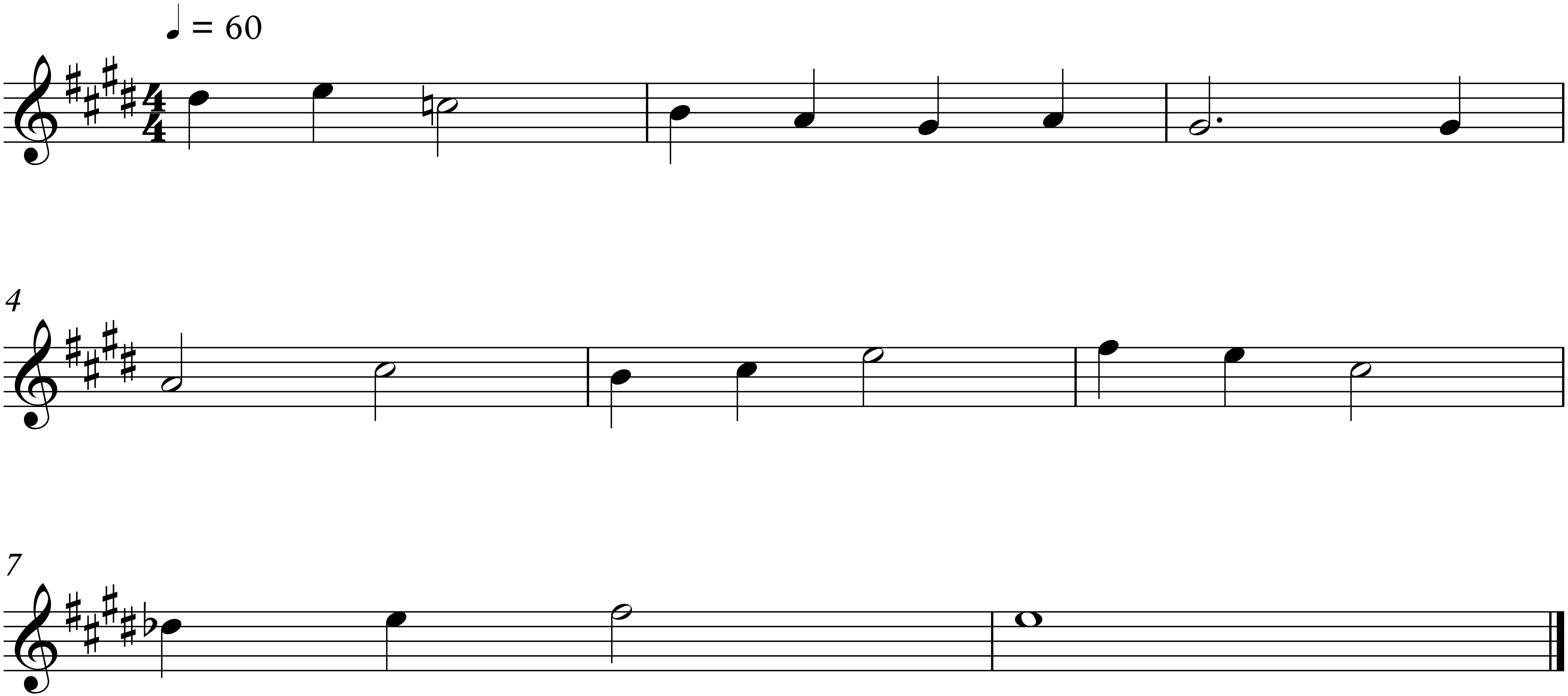
Appendix E 5

Appendix E 6

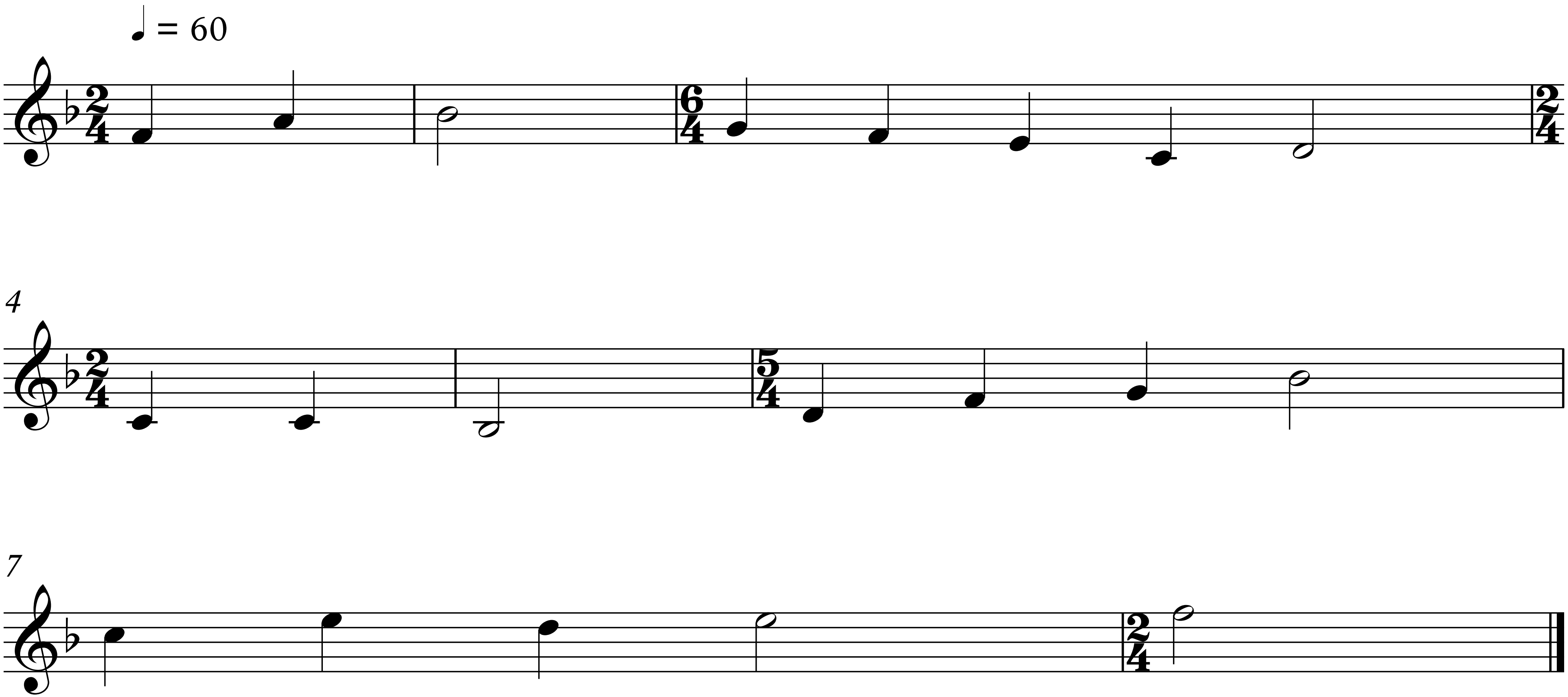


Appendix E 7

Appendix E 8

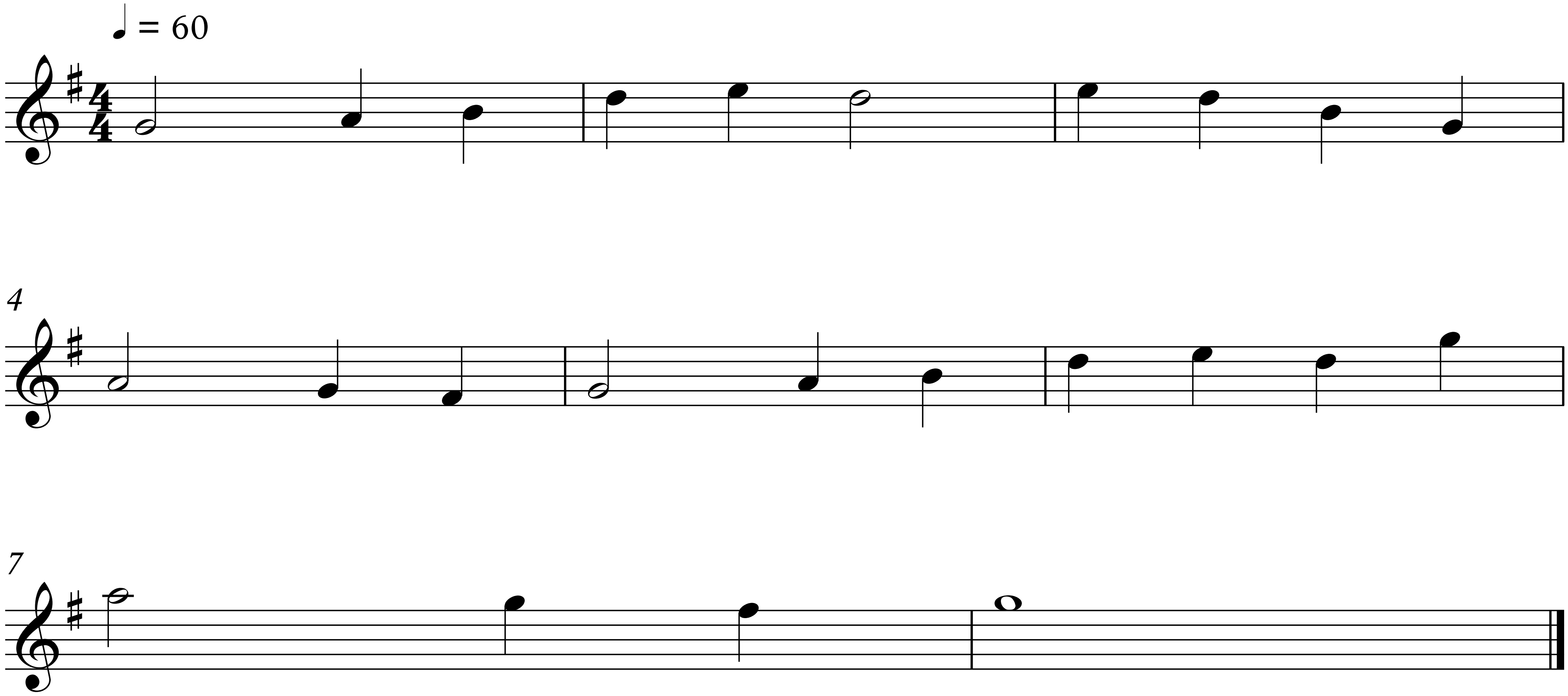


Appendix E 9



Appendix E 10

Appendix E 11



Appendix E 12

Appendix E 13

Appendix E 14

Appendix E 15

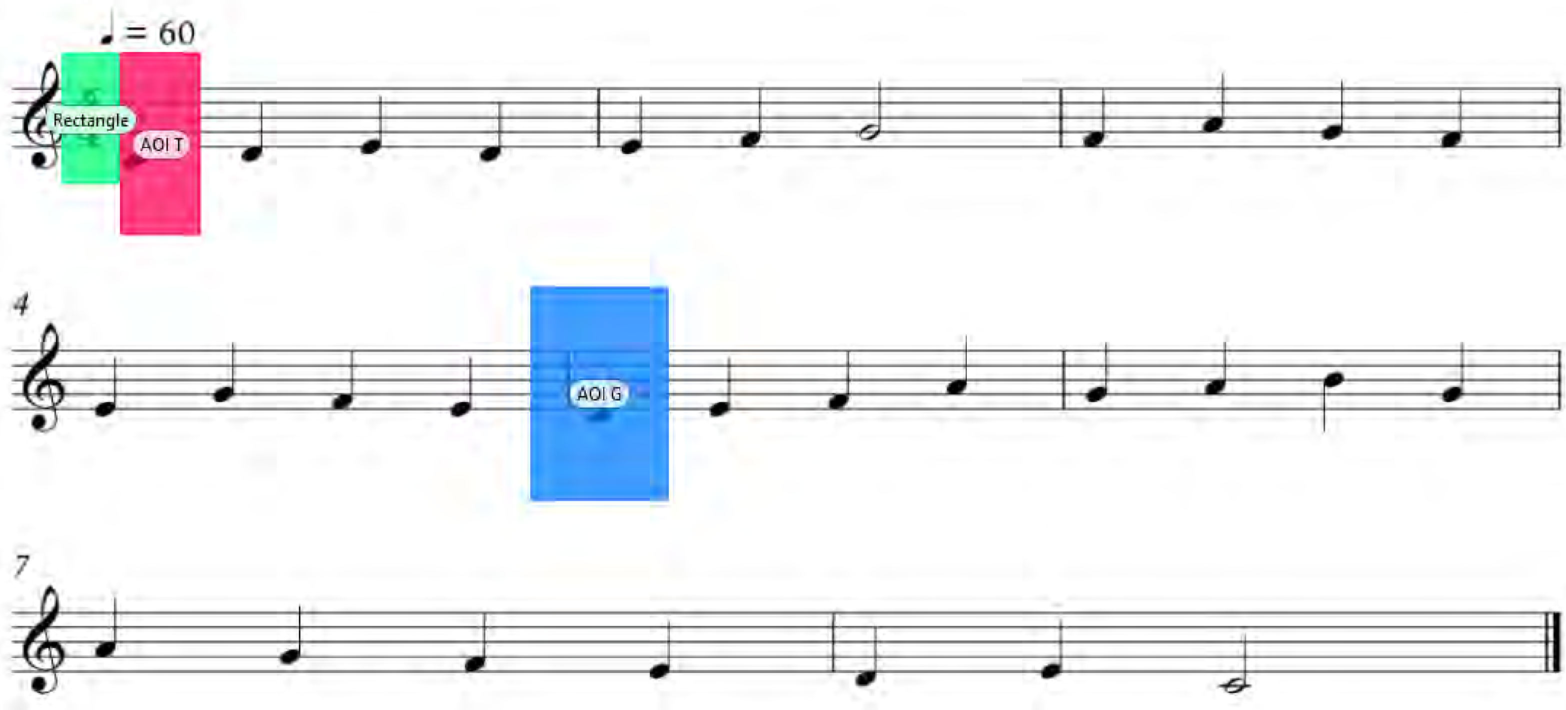
Appendix E 16

Appendix E 17

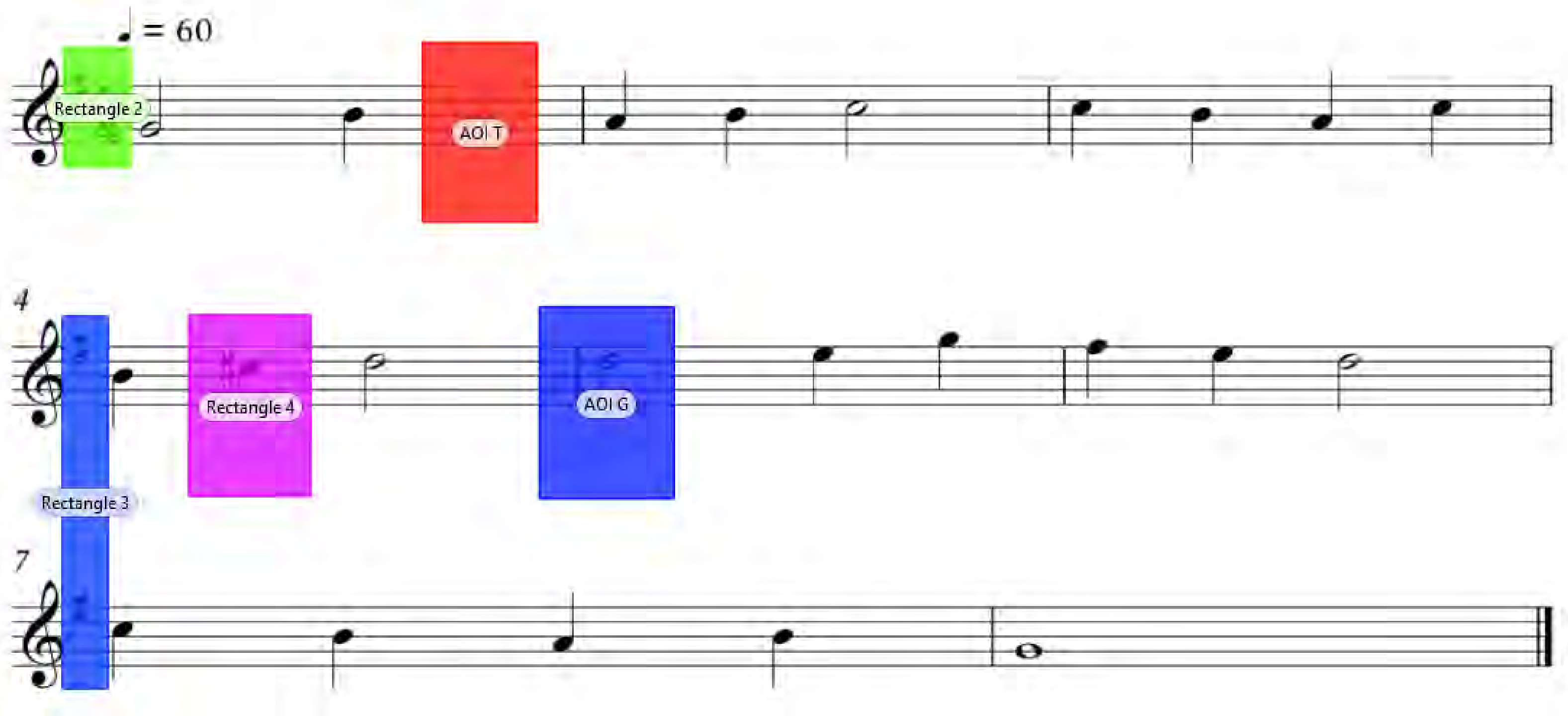
Data Collection Protocol (Appendix F)

1. Ask participant whether he/she is comfortable being video taped during the data collection process. If consent is given, the camera is set to record the proceedings.
2. Enquire whether he/she read the informed consent form that was emailed to hin/her prior to data collection. If not, then provide with a hard copy. Regardless of answer, request that participant signs an informed consent form, providing time for any questions he/she may have regarding the process.
3. Ask participant to sit at the piano, making adjustments to the chair height if needed.
4. Explain the presence of the Tobii specialist in the room. The Tobii specialist then adjusts the monitor stand to accommodate for the height of the participant. Ask Tobii specialist to explain the calibration process. Once participant understands, perform calibration. Participants are asked to focus and follow a moving red dot on the monitor screen. If the calibration process produces inaccurate results, the inaccurate points are recalibrated until they are sufficiently accurate.
5. Explain the data collection process to participant, following these steps:
    - The process consists of a slide show.
    - The first slide will be a red dot on a white background (called a rest slide). Participant is asked to look at the red dot whenever such a slide appears.
    - The second slide will be a standardised Trinity College London Grade 6 piano sight reading. This is to be performed in the participant's own time and tempo.
    - Once this is complete, a black slide will appear repeating all verbal instructions. Participant may ask questions if he/she does not understand the research process.
    - After this slide, a rest slide will appear followed by a sight-reading example for the right hand only. The metronome (set at 60 beats per minute) will be used for the remainder of the data collection. The rest slide will remain on the screen for 4 metronome counts. The sight-reading example will follow. The participant is to wait for four metronome counts before starting to play. The researcher will aid participants by counting each of these (silent) beats out loud.
    - 11 more examples will follow, each preceded by a rest slide.
    - Test 1 will conclude with a black slide indicating the end of test 1.
    - The calibration process is repeated in preparation for Test 2.
    - Test 2 will start with a black slide explaining instructions again. Participants are given an opportunity to ask questions if anything is unclear to them.
    - 5 sight-reading examples will follow (to be played by both hands). Each example is preceded by a rest slide. The same metronome conditions will apply.
6. Once the participant acknowledges that he/she understands the procedure fully, the data collection process is performed. Test 1 is done without stopping, followed by a brief break and then Test 2 is performed without stopping.
7. Upon completion of both tests, the video camera is stopped and the participant thanked for their participation in the study.
8. If they wish, they are given the opportunity to see their gaze patterns as recorded by the eye tracker in the Tobii software.
9. The entire process lasted just under 30 minutes for every participant.

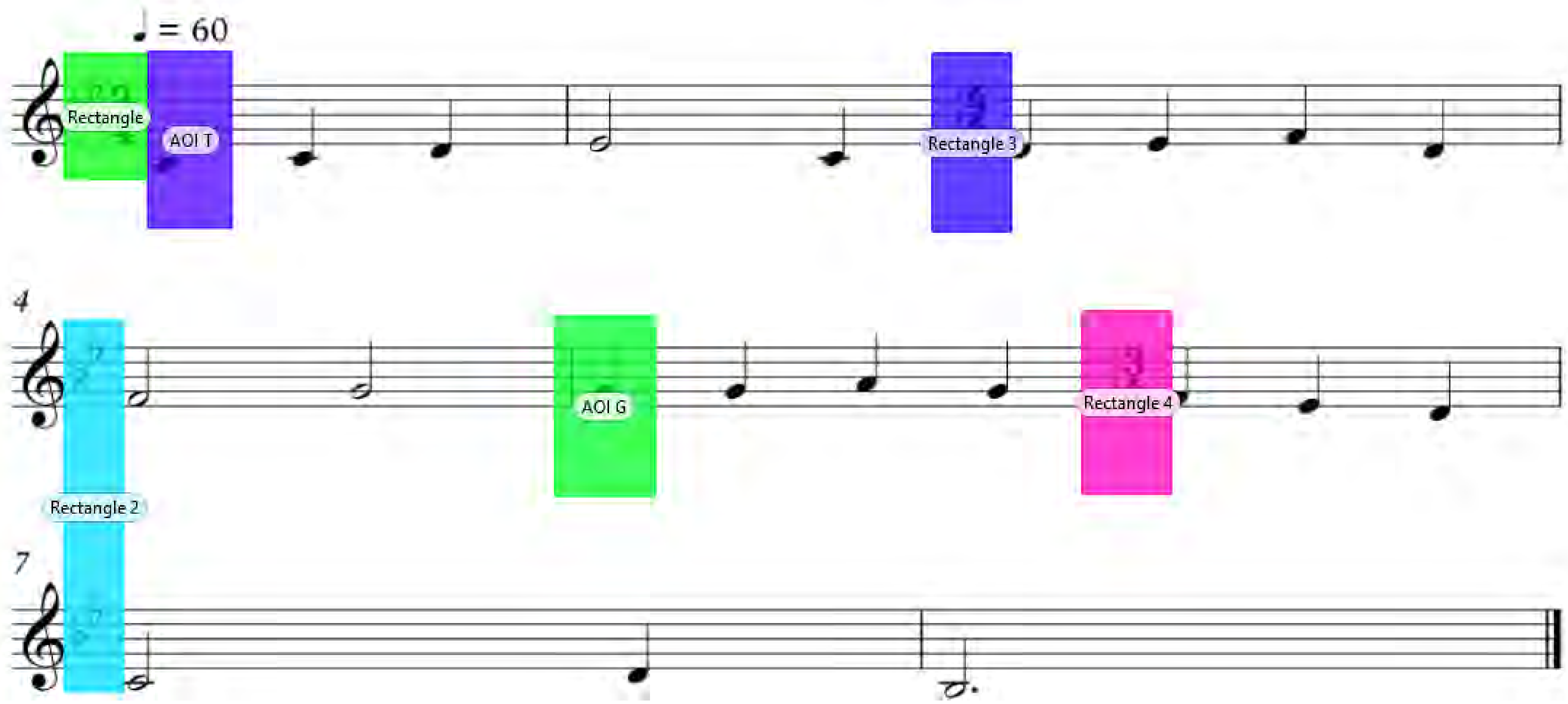
Appendix G 1



Appendix G 2

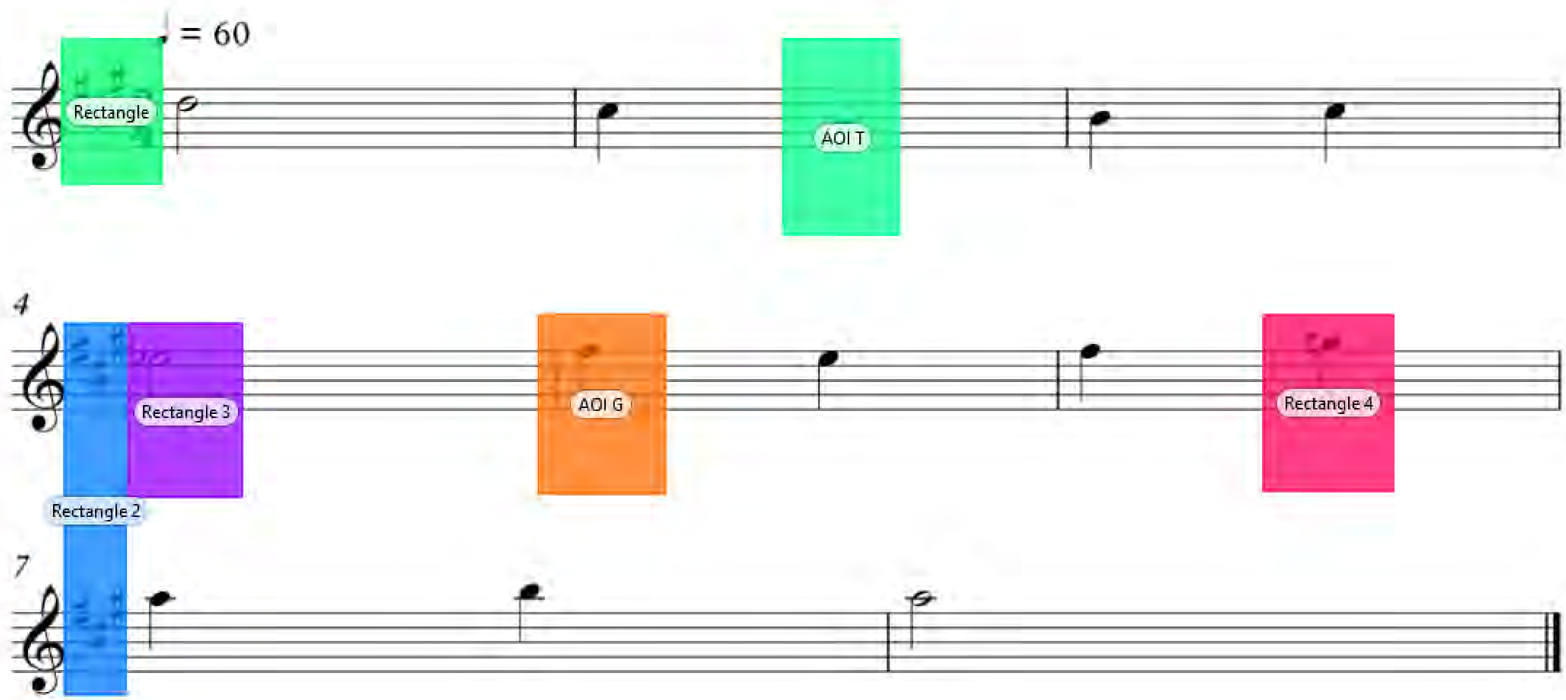


Appendix G 3

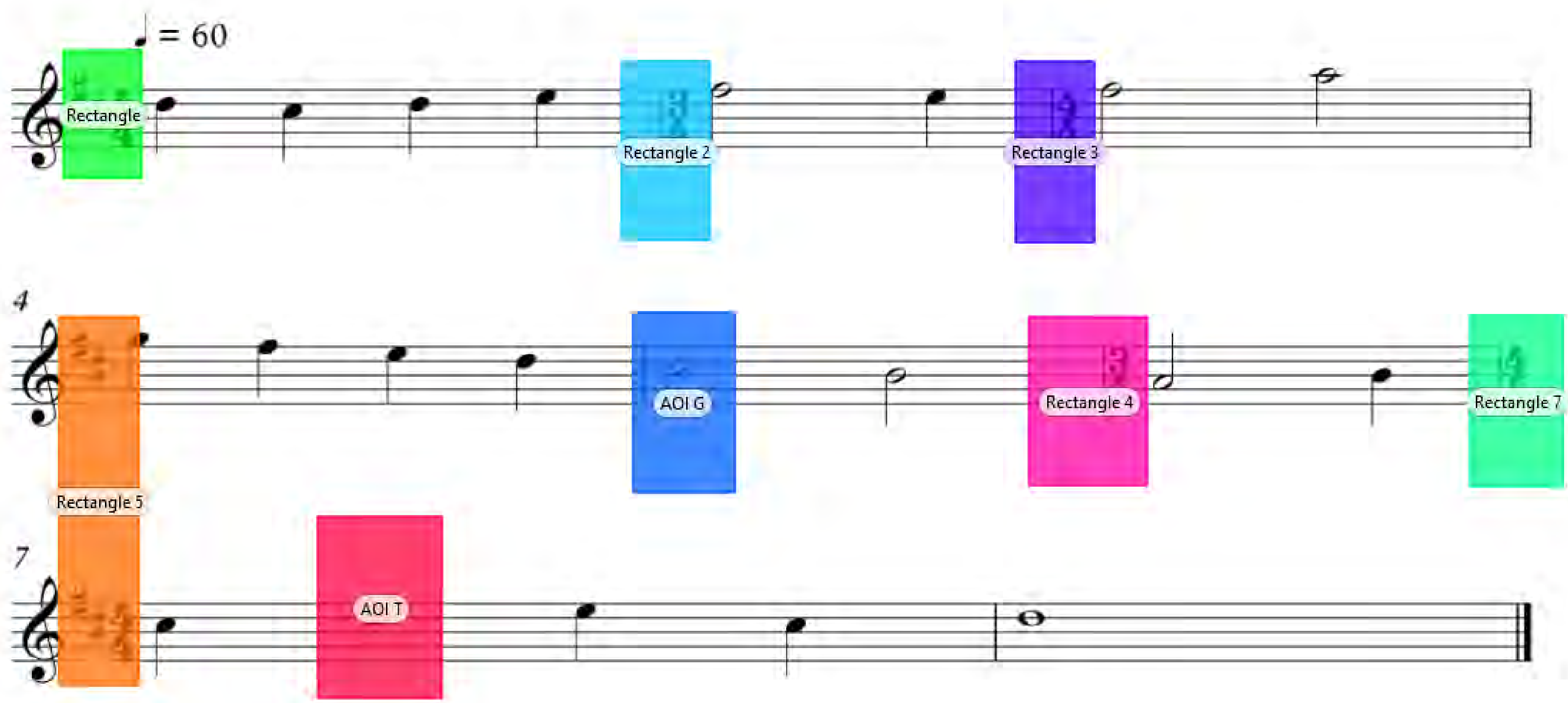


♩ = 60
Rectangle
AOI T
Rectangle 3
4
AOI G
Rectangle 4
Rectangle 2
7

Appendix G 4

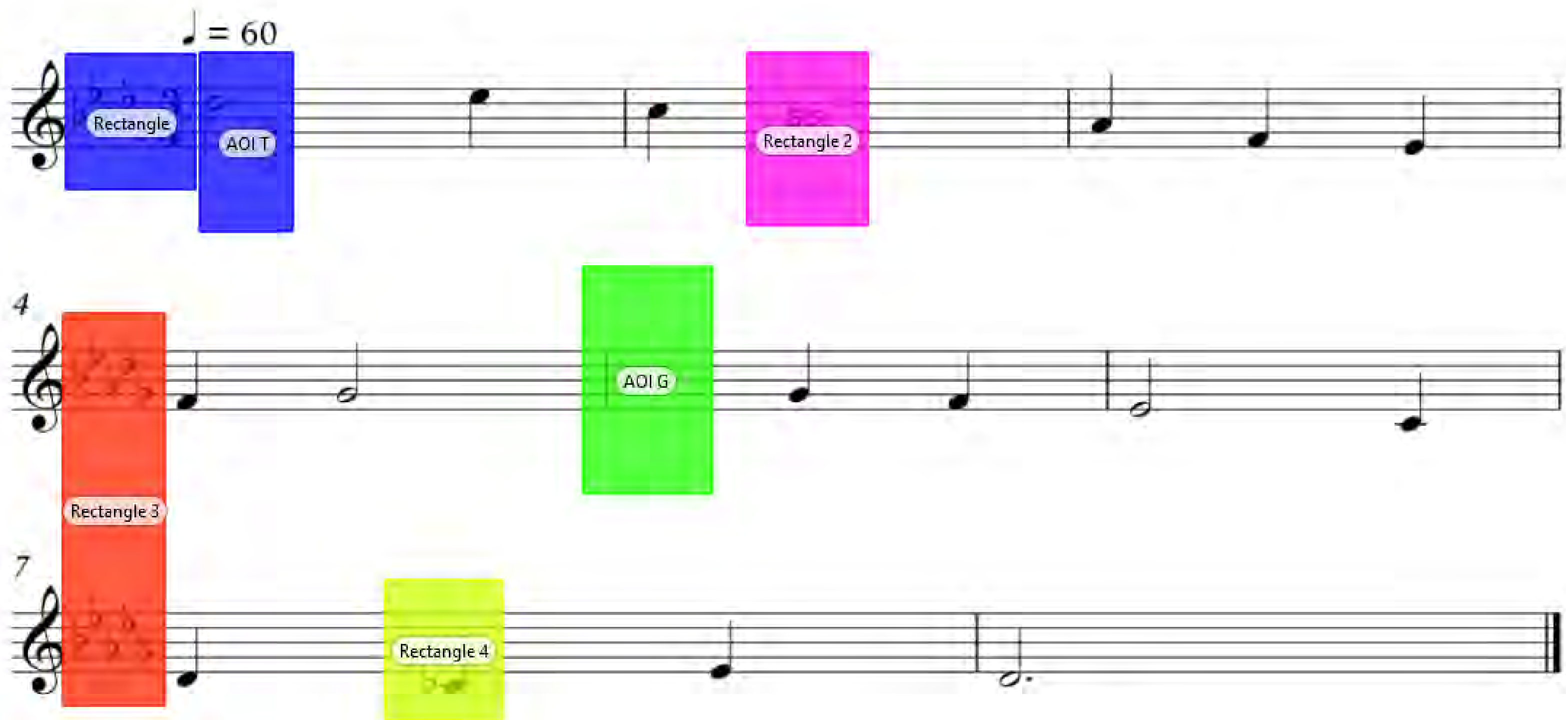

= 60
Rectangle
AOI T
4
Rectangle 3
AOI G
Rectangle 4
Rectangle 2
7

Appendix G 5



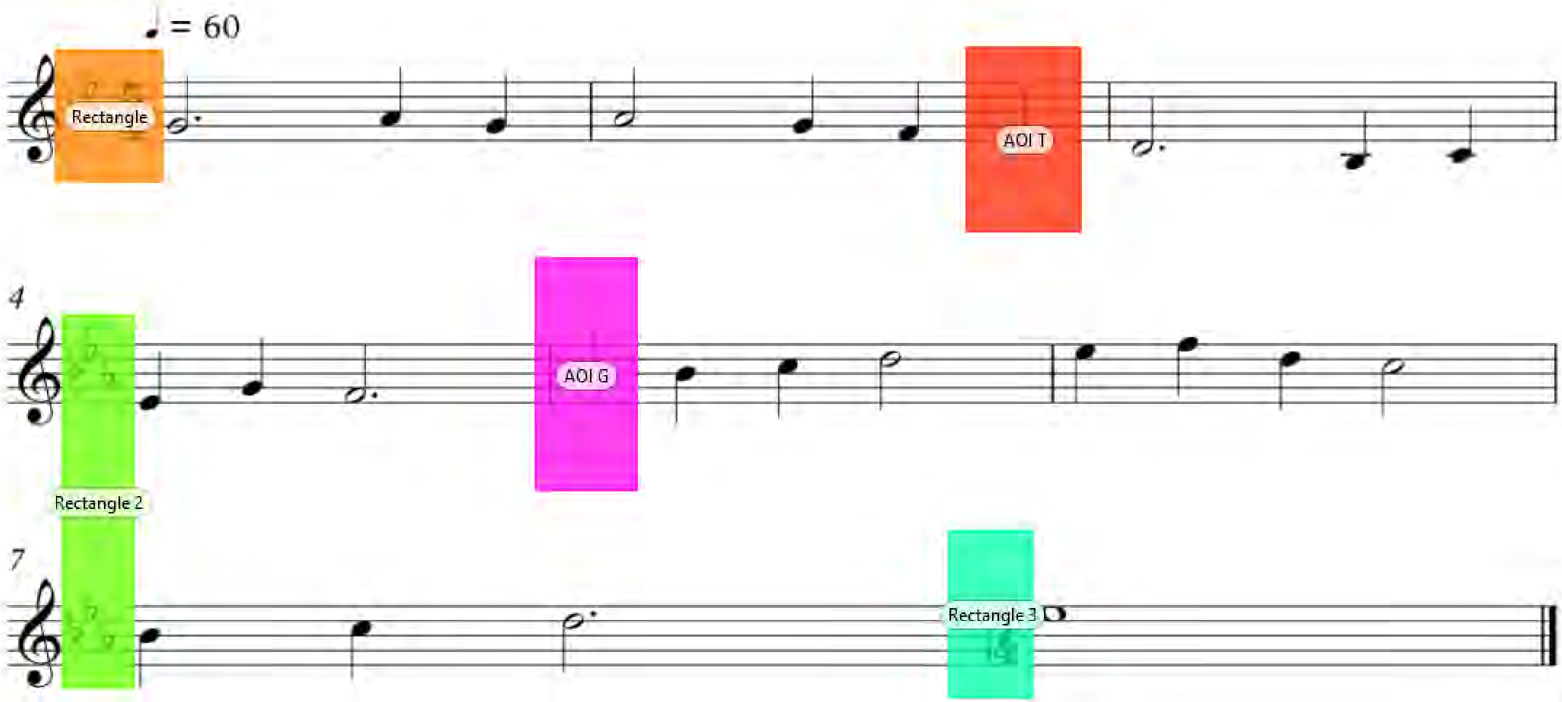
♩ = 60
Rectangle
Rectangle 2
Rectangle 3
4
AOI G
Rectangle 4
Rectangle 7
Rectangle 5
7
AOI T

Appendix G 6



♩ = 60
Rectangle
AOI T
Rectangle 2
4
Rectangle 3
AOI G
7
Rectangle 4

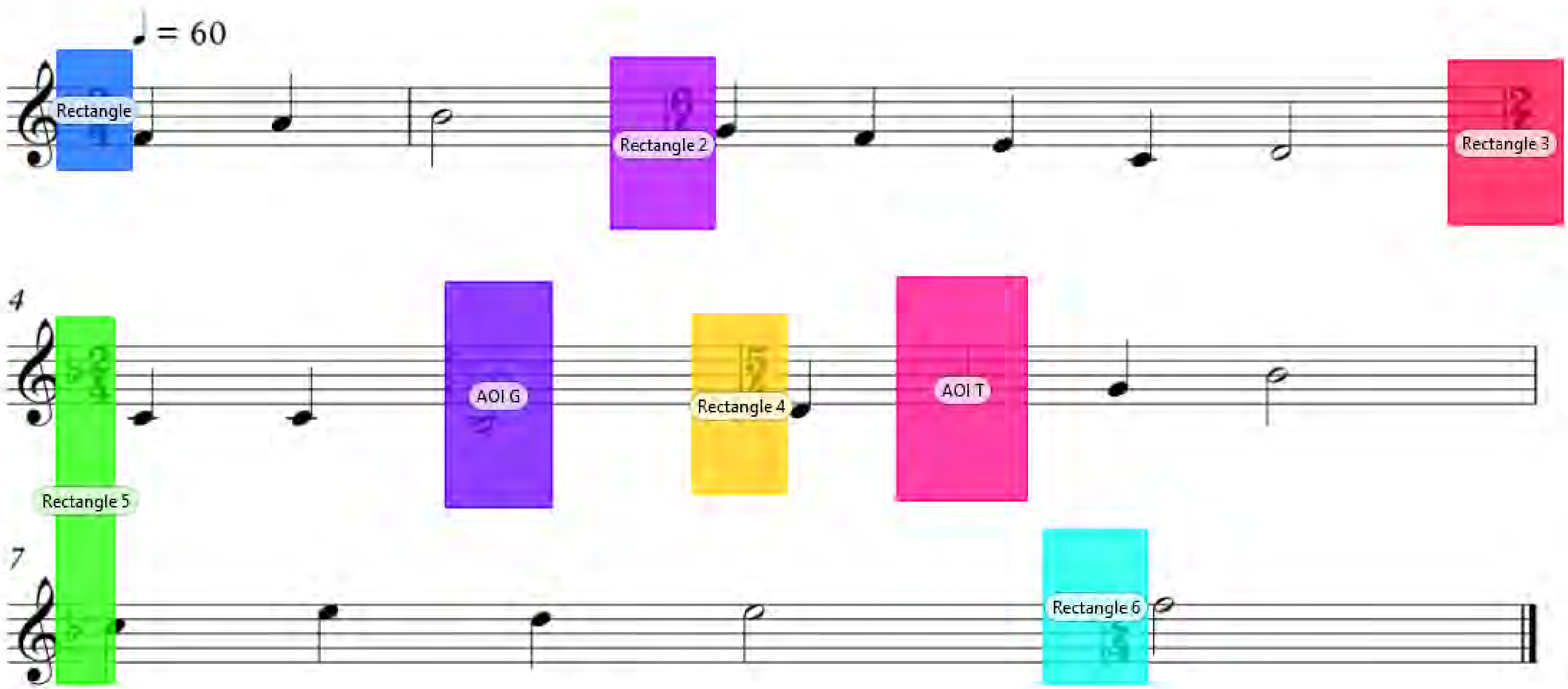
Appendix G 7



Appendix G 8

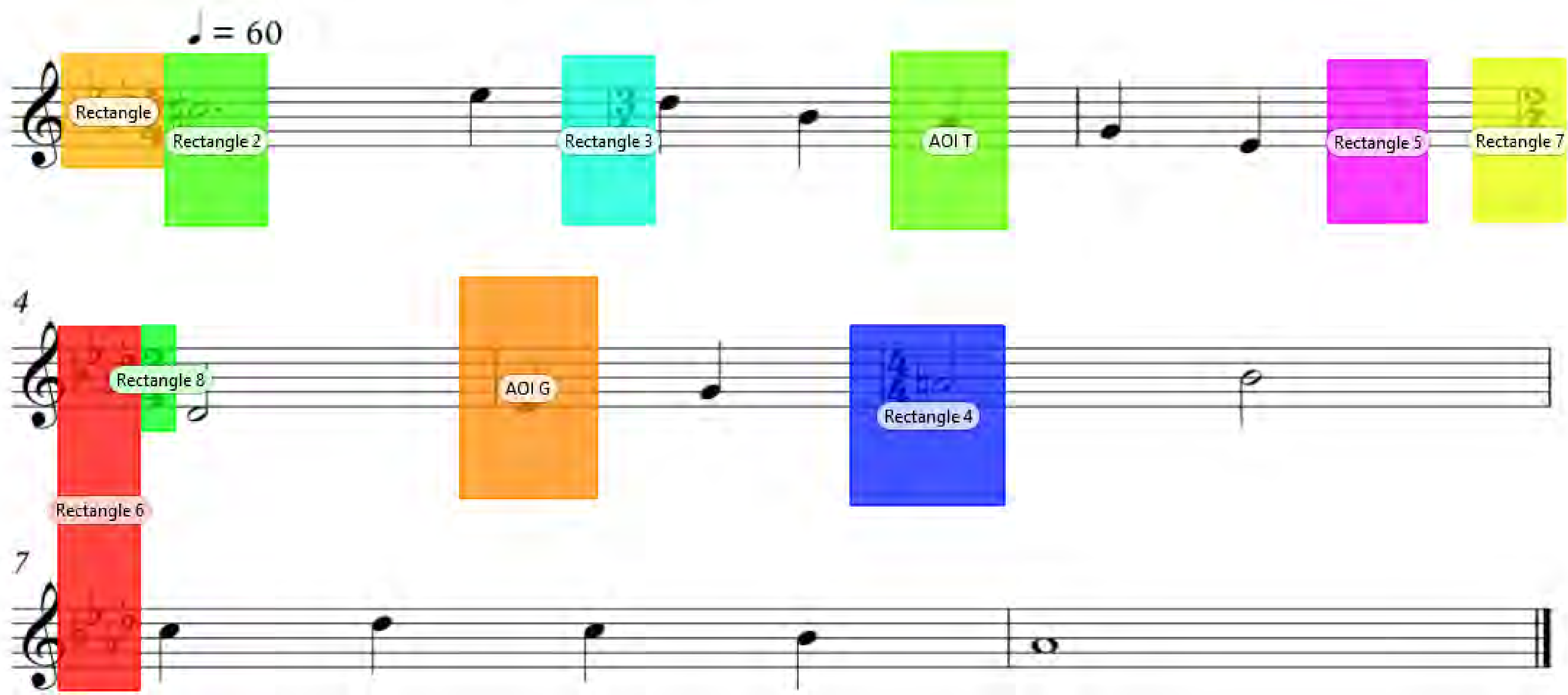
♩ = 60
Rectangle
Rectangle 2
4
AOI G
AOI T
Rectangle 3
7
Rectangle 4

Appendix G 9

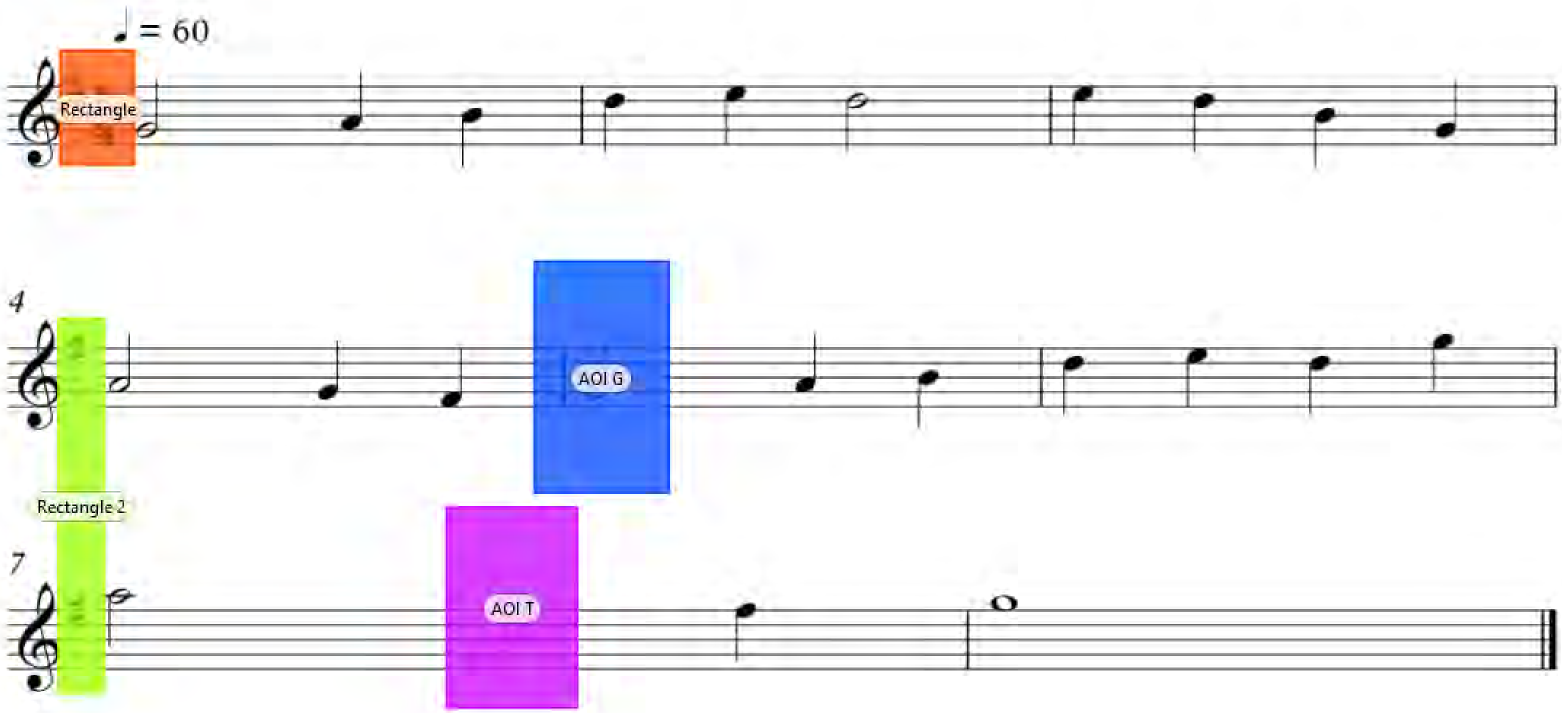


♩ = 60
Rectangle
Rectangle 2
Rectangle 3
4
AOI G
Rectangle 4
AOI T
Rectangle 5
7
Rectangle 6

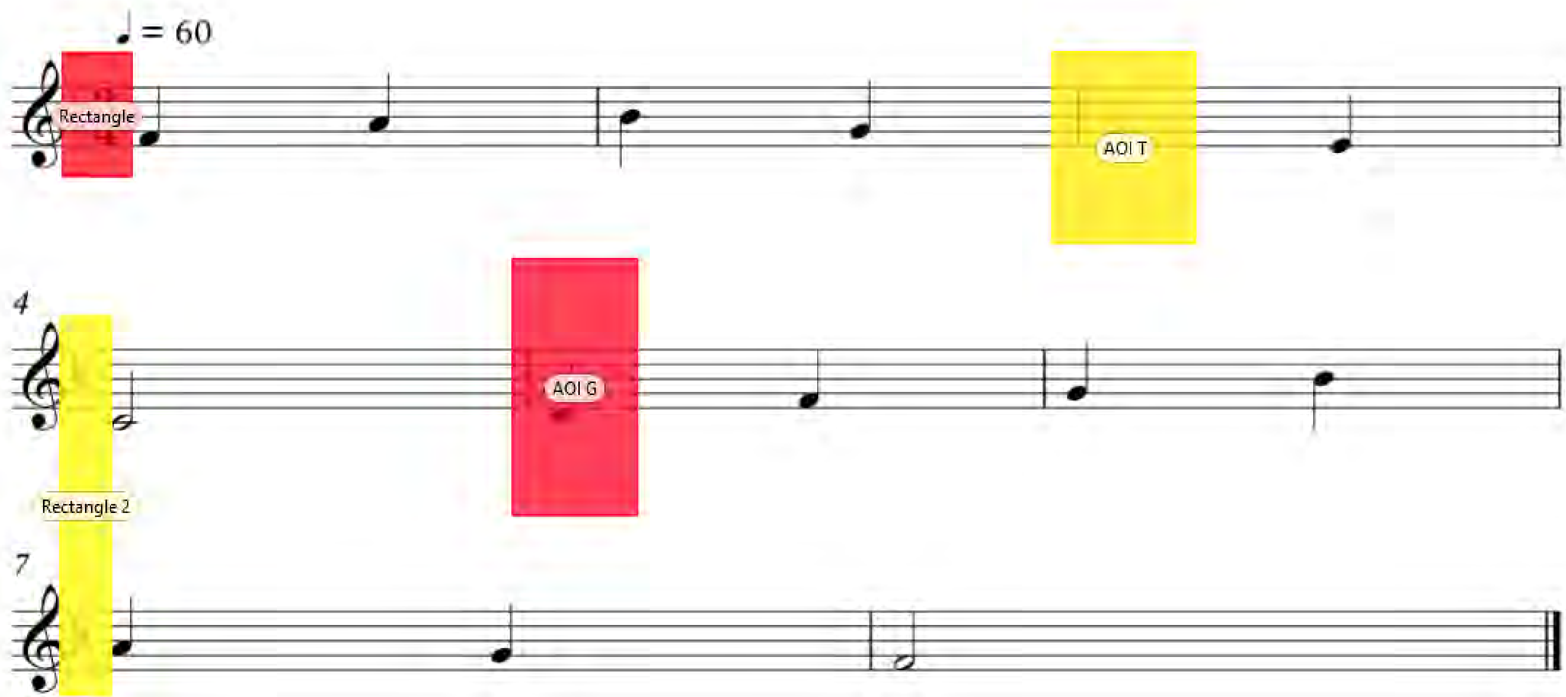
Appendix G 10



Appendix G 11



Appendix G 12



Appendix G 13

Appendix G 14

Appendix G 15

Appendix G 16

Appendix G 17

RHODES UNIVERSITY
Where leaders learn

Human Ethics subcommittee
Rhodes University Ethical Standards Committee
PO Box 94, Grahamstown, 6140, South Africa
t: +27 (0) 46 603 8055
f: +27 (0) 46 603 8822
e: ethics-committee@ru.ac.za

www.ru.ac.za/research/research/ethics
NHREC Registration no. REC-241114-045

Appendix H

1 July 2019

Jacobus Viljoen

Reference number: 2019-0361-627

Email: g19v7651@campus.ru.ac.za

Dear Jacobus Viljoen

Re: Gaze patterns of skilled and unskilled sight readers

Principal Investigator: Prof Catherine Foxcroft

Collaborators: Mr JF Viljoen ,

This letter confirms that the above research proposal has been reviewed and **APPROVED** by the Rhodes University Ethical Standards Committee (RUESC) – Human Ethics (HE) sub-committee.

Approval has been granted for 1 year. An annual progress report will be required in order to renew approval for an additional period. You will receive an email notifying when the annual report is due.

Please ensure that the ethical standards committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Sincerely

Prof Joanna Dames

Chair: Human Ethics sub-committee, RUESC- HE