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Multimodal learning for dyslexic musicians: Practical applications for adults

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Practical Applications for Adults

This dissertation is submitted as part of the requirements of the degree of

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Abstract

Dyslexia affects 15 to 20% of the population according to the International Dyslexia Association. Multimodal media, such as smartphones and tablets, which are capable of presenting varied modes of information (for example, visual, aural, and kinetic), have been shown to aid learning in dyslexic children. Music has been identified as a useful multisensory tool to help educators improve literacy skills in children. However, little research has been done on the impact of dyslexia on a child or adult's ability to learn and perform music. Few studies have been undertaken that focus solely on dyslexia's effect on musical ability in children; even fewer address dyslexia in adult musicians. This study summarises the techniques and suggestions in the literature used by both professional dyslexic musicians and educators of dyslexic children. It is hoped that this summary can inform the creation of a resource that assist musicians and their educators to use in tackling the challenges dyslexia can pose in learning and performing music. A proposed customisable music reading application is described in detail. This application would utilise the multimodal nature of tablet computers and smartphones to suit the learning styles of dyslexic musicians.

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Table of Contents

Table of Figures

List of Tables

Chapter 1: Introduction

Approximately 15% to 20% of the world's population has some form of dyslexia (International Dyslexia Association, 2017, p. 1). Dyslexia is often characterised by difficulties in literacy acquisition affecting reading, writing and spelling (Reid, 2016, p. 5). There is some controversy as to whether dyslexia may affect one's ability to play music because there is little empirical evidence that suggests a type of musical dyslexia exists. This may be due to dyslexia's large range of symptoms and its varying levels of severity from person to person (as discussed in Section 1.2 below; Reid, 2016, p. 3). However, there are multiple anecdotal accounts of dyslexic musicians struggling with dyslexia, as well as studies that have begun to investigate the relationship between dyslexia and music (Bishop-Liebler, Welch, Huss, Thomson, & Goswami, 2014; Ganschow, Lloyd-Jones, & Miles, 1994; Habib et al., 2016; Nelson, 2014). For the scope of this study, I have focused on the anecdotal experiences of musicians who experience difficulties with dyslexia in their musical endeavours and their educators, rather than trying to discover or prove if a type of 'musical dyslexia' exists.

Despite not being formally diagnosed as dyslexic, I recognise some of the symptoms of dyslexia in my own musical endeavours. I have found that the biggest challenge through the course of my undergraduate music studies has not been technical or musical in nature but rather my ability to effectively read and process large quantities of notation. To overcome this hurdle, I looked to music literature and educators to help me learn new methods to better deal with my difficulties. Unfortunately, I found little help, as the literature and methods that were available either did not exist in a formalized manner or did not apply to my circumstances because they dealt with children's education and did not translate well to mature musical concepts. Most of the literature I found that discussed dyslexia and music was

focused on helping dyslexic children improve their literacy skills, with only a limited number of sources related to assisting dyslexic children to learn music. (as disscused in section 1.2; Bishop-Liebler et al., 2014; Ganschow et al., 1994; Habib et al., 2016; Nelson, 2014; Reid, 2016, p. 3)

Professional musicians with dyslexia do exist and can be highly successful. Although some personal accounts analyse the methods used by dyslexic professional musicians, none provide an extensive cross-medium synthesis of each individuals' compensatory strategies. In this dissertation, I begin by discussing what dyslexia is and how its symptoms manifest (Sections 1.1 and 1.2). This is followed by a brief look in to the merits of multimodal media as a tool to aid the education of dyslexic children (Section 1.3). In Chapters 2 and 3 I collate and summarise techniques, strategies, and methods found in a review of the literature and of published case studies to create an easily accessible collection of such techniques for dyslexic musicians to utilise, regardless of their age or musical ability (See Section 3.3). Chapter 4 investigates how these techniques may be applied through a digital medium to create a multimodal application that could assist dyslexic musicians to customise their music reading experiences to ease the effects of dyslexia. Finally, Chapter 5 discusses possible further avenues for this research and closing remarks. Through this research, I hope to not only discover new methods of learning for myself, but to provide a starting point for other adult musicians with learning difficulties similar to those experienced by people with dyslexia.

1.1 - What is dyslexia?

There are three forms of dyslexia: primary dyslexia caused by cerebral cortex damage, trauma dyslexia caused by brain trauma, and developmental dyslexia (Heikkila & Knight, 2012, p. 54). Developmental dyslexia (DD) will be the focus of this study. The exact definition of DD is hard to establish as the symptoms of dyslexia can manifest very

differently from person to person. For the purpose of this study, the definition provided by Reid (2016) in his book *Dyslexia: A Practitioner's Handbook* will be used:

> Dyslexia is a processing difference, often characterised by difficulties in literacy acquisition affecting reading, writing and spelling. It can also have an impact on cognitive processes such as memory, speed of processing, time management, coordination and automaticity. There may be visual and/or phonological challenges and there are usually some discrepancies in educational performances. (p. 5)

This study has approached dyslexia and its relationship with music from a social sciences perspective in an attempt to gather practical strategies that musicians can use to manage dyslexia's effects on music-making. Another aspect of this topic is to study the neuroscience behind DD and its relationship to music – this is a natural extension of this study and is addressed in the discussion in Chapter 5, where possible further research is discussed. The neurological aspects of dyslexia form a complex and large field of study and are therefore out of scope for this focussed discussion of the relationship between dyslexia and music that I am presenting as part of my Honours studies in Music. They are therefore not discussed here in detail. This study uses the terms non-dyslexic and dyslexic to differentiate between those people with dyslexia and those without. The term neuro-typical has been used in related literature regarding this topic to describe non-dyslexic people but has been avoided herein because the underlying implications of the term address the brain science behind DD, which is beyond the scope for this study.

1.2 - What are the signs of dyslexia?

Miles et al. (2008, p. 3) suggest that dyslexia should be characterized as a syndrome and not a disability, as a syndrome better describes the cluster of symptoms displayed by dyslexia. They believe this is important because dyslexia can manifest very differently from person to person. For instance, one individual may display the 'more common' symptoms such as poor literacy skills, whereas another equally intelligent individual may have no difficulties with literacy but have problems understanding mathematical and musical symbols. This is commonly how dyslexia goes undiagnosed: with literacy skills being the focus of traditional western education, those who struggle with other notation systems or who are not severely dyslexic can be overlooked. Some of the possible manifestations of dyslexia can be poor time-management, poor spelling, poor motor skills (also referred to as dyspraxia), problems with 'left' and 'right', poor short-term memory, difficulty understanding written text, low self-esteem, and poor handwriting (also referred to as dysgraphia; Miles et al., 2008, p. 6).

1.3 - Multimodal media

Individuals with dyslexia commonly have difficulty recognizing and understanding notation systems, whether that be the recognition of the written language or musical notation. By utilizing different learning inputs such as physical movement (kinesthetic learning), symbols and pictures, and sound, dyslexic learners may be able to cross reference the meaning of a section of written text or collection of symbols with information established by the other sensory inputs (Vincent, 2008, p. 32). Vincent observed that when students with dyslexia were able to present their findings through a variety of media − in a "multimodal"

fashion − they were better able to express their ideas than with verbal presentations alone. Vincent calls the crossing of semiotic modes (relating to signs and symbols) transmediation, stating that information is "initiated in one symbol and re-expressed in another" (p. 32).

1.4 - Aims and research question

This study aims to provide a summary of practical strategies and techniques dyslexic musicians and their music educators can utilise to overcome the difficulties associated with dyslexia and music learning. The research question of this thesis is: How might multimodal techniques used to assist dyslexic children learning music be applied and adapted to assist adult musicians?

Aims

1   To compile a list of techniques used by music educators to help dyslexic children.

2   To analyse and compare techniques suggested by dyslexic adult musicians.

3   To investigate whether these techniques can be modified and how they may be applied to a digital notation application to assist mature dyslexic learners in reading music notation.

Chapter 2: Literature Review

2.1 - Music and dyslexia

The symptoms of dyslexia are different in musicians in relation to musical ability when compared to the impact of dyslexia on a person's literacy. Being able to recognize the symptoms of dyslexia's effects on music ability is the first step in understanding how to overcome its effects. O'Brien Vance (2004, p. 28) outlines that a dyslexic musician may have:

- difficulty reading musical notation

- a poor working memory

- low self-esteem

- poor motor skills (difficulty learning instrumental fingerings)

- difficulties with rhythm

- difficulties discerning 'right' and left', for example, knowing which hand to play a melody on the piano with

- difficulties processing large quantities of information (linked to poor sight-reading)

- difficulties with sequences (difficulties playing notes in the correct order or following a sequence of instructions)

2.2 - Music as a multimodal tool to improve literacy in dyslexic children

The action of making music involves phonological, kinaesthetic, and rhythmic aspects and is proven as an effective multimodal tool to help dyslexic children improve their literacy skills (Habib et al., 2016; Overy, 2003; Rolka & Silverman, 2015). Overy (2003, p. 503) observed significant improvement in phonological and spelling skills after introducing a variety of basic rhythm, meter, and pitch skills in the classroom. The development of the Cognitivo-Musical Training (CMT) method by Habib (2016, p. 1) yielded promising results with dyslexic children. After participating in a six-week training course, participants showed significant improvement in auditory attention, reading abilities, repetition of pseudo-words, and phonological awareness (syllable fusion). Habib's CMT method uses a combination of activities, starting with simple tapping tasks, then moving to use a piano to help with visuospatial organization. Wherever possible, body movement was encouraged during activities to link kinesthetic skills with timing and rhythm. Finally, speech and music were applied at the same time to encourage phonological and rhythmic connections.

2.3 - Methods to help dyslexic children learn music

A small number of studies address how to assist dyslexic children in learning music. Researchers such as O'Brien Vance (2004) and Heikkila and Knight (2012) have compiled teaching strategies for educators to employ when teaching music to elementary-aged children with DD. Both O′ Brien Vance and Heikkila and Knight have complied these teaching strategies through their experiences as music educators of young children, including those with dyslexia. As a musician with dyslexia, O′ Brien Vance also expresses her appreciation for "how difficult and how rewarding the study of music can be″ (O'Brien Vance, 2004, p.

27). Although these studies lack scientific backing, O'Brien Vance and Heikkila and Knight's experience as music educators combined with the anecdotal evidence presented is invaluable and should still be regarded as a valuable resource.

2.3.1 - Modifying written materials and scores

The first and often the easiest strategy to implement in the classroom is providing modified written materials, for example, enlarging scores or printing manuscripts on pastel-coloured paper (Heikkila & Knight, 2012, p. 56; O'Brien Vance, 2004, p. 29). Heikkila and Knight (2012, p. 56) suggest that enlarging scores helps 'reduce information overload' as instructions and details are better spread out and easier to read. This is supported by Solook (2015, p. 51), who found enlarging scores and separating voicing and parts helped improve font clarity and made expression markings, dynamics, and articulations easier to read. Irlen Syndrome (a visual perception disorder that is often seen in dyslexic students and those with similar learning difficulties such as autism and Attention-Deficit/Hyperactivity Disorder (ADHD)) can cause symptoms such as eye strain, sensitivity to bright lights, difficulties reading, headaches, and fatigue (Irlen Association). Although Irlen Syndrome does lack some backing from empirical evidence, suggestions made by O'Brien Vance, Heikkila and Knight and Solook show similar results from using pastel-coloured paper to ease reading in people with dyslexia to subjects with Irlen syndrome and thus it has been acknowledged here. Printing materials and scores on pastel-coloured paper may assist a dyslexic learner by reducing the effects of Irlen Syndrome because it reduces the contrast of the information (black) and the page (white) making it easier to read and stay focused (Irlen Association).

A study by Flach et al. (2016, p. 243) concluded that the number of mistakes made by

dyslexic music students was reduced by enlarging the staves and by writing all the stems of notes in the same direction. Stem direction does not always correlate to the pitch of the note however, and this approach may sometimes confuse dyslexic readers. More research is needed to investigate the effect of stem directions. Educators may nonetheless find this useful for teaching beginner notation.

2.3.2 - Aural skills

Both O'Brien Vance (2004, p. 29) and Heikkila and Knight (2012, p. 58) strongly endorse singing or playing along with the student during lessons as it provides students with an example of a good quality sound and may help a student better audiate the sound they wish to produce. Hubicki (1991, p. 63) also encourages the provision of good-quality recordings for students because this achieves similar effects to singing and playing in a lesson. The Kodály method may also be useful for dyslexic learners (Ganschow et al., 1994, p. 198). By assigning speech rhythms such as Ta (representing a single beat) and Ti-Ti (representing a half-beat), the Kodály method removes the numeric value associated with standard notation, isolating the idea of rhythm from its notated counterpart, thus allowing students with DD to learn rhythm without the need for understanding its associated symbols (Ganschow et al., 1994, p. 198).

2.3.3 - Rhythm and body movement

Incorporating body movement and speech when teaching rhythm exercises can help students to transmediate their knowledge by utilising multisensory experiences. As students with DD often struggle with feeling the beat and therefore struggle to place rhythms within it,

using the body during rhythm exercises may help a student internalize the beat (O'Brien Vance, 2004, p. 30). Breaking down music into individual tasks can allow a student with DD to focus solely on one aspect of the music and avoid information overload (Nelson, 2014, p. 178; O'Brien Vance, 2004, p. 30; Solook, 2015, p. 51). This may entail just practicing the rhythm by clapping, practicing intervals and melody individually, or working on the general dynamic contour on one note. These can then be slowly recombined creating a better overall understanding of the passage. Including body movement in learning combines kinetic, aural, and visual skills, creating multisensory learning experiences that are more beneficial for dyslexic learners than traditional static learning methods (Hubicki & Miles, 1991, p. 76; O'Brien Vance, 2004, p. 29).

2.3.4 - The use of colour

Associating colour with musical notation has been identified by many educators as an effective multimodal tool to assist dyslexic children with learning music. O'Brien Vance (2004, p. 29) and Heikkila and Knight (2012, p. 56) suggest using colour to highlight instructions or notation that would otherwise be ignored. An example of this could be assigning different colours to dynamics or specific notations like staccato to create a 'musical road map' for the students to follow. Another commonly used method is Hubicki and Miles's (1991) Coloured Staff, in which each letter name is assigned to a specific colour and provides students with a large grand staff with tangible materials to represent clefs, crotchets, and other musical symbols. The use of the Coloured Staff allows students to identify patterns visually and kinetically because they can move their fingers up and down to follow along with the notes. This method avoids having the students associate notation with their respective labels, helping them learn staff notation in isolation from rhythm and other musical

elements. A study by Rogers (1991) examined the effectiveness of colour-coded method books in which each pitch was highlighted with a different colour but found no clear improvement between controls and those who used the colour-coded method books.

2.3.5 - Technology as a multimodal medium

Over the last 15 years, technology, especially computer tablets, has been recognized as a powerful educational tool. The multisensory nature of tablets makes them especially effective in educating those with learning difficulties such as dyslexia. Baker (2007, p. 19) observed a significant improvement in student engagement and an increase in learning speeds after introducing a Smart Board into the music classroom. Baker found the Smart Board made it easier to show images and play musical excerpts, not only assisting in the creation of lessons but improving the quality of the material. In a more recent study, Witmer (2015) sought to identify if a tablet computer could be used as a multimodal tool to assist dyslexic children to learn staff notation. An app was created, consisting of several basic notation games that increased in difficulty with each level. When used in conjunction with regular class music instruction, the app significantly improved the students' ability to recognize musical staff notation. Witmer attributed this to the tablet's ability to provide visual, tactile, and aural cues, allowing students to transmediate the information presented to better contextualize what notation represents.

2.3.6 - Environmental factors

It is not just how we learn, but where we learn and with whom that can have a significant impact on the quality of the educational experience. People with dyslexia

commonly have poor self-esteem, as they often do not excel in a literacy-based education system, and take this to be an indication of their intelligence, which is usually far from the truth (O'Brien Vance, 2004, p. 28). O'Brien Vance (2004, p. 29) and Heikkila and Knight (2012, p. 59) both emphasise the importance of frequent encouragement and feedback. O'Brien Vance specifically mentions asking the student to be specific, and kind, in self-criticisms: instead of "that was bad" try "I struggled with this rhythm" (p. 29). Solook (2015, p. 50) also concludes that having outside motivators such as participating in ensembles, lessons, and talking about music with colleagues and friends can be beneficial because practicing music can be very tiring due to its need for intense focus. Heikkila and Knight (2012, p. 56) goes on to discuss the placement of the student with DD in the classroom, suggesting that a student with DD may benefit from sitting next to another student of higher musical ability, reasoning that it may assist them to maintain focus and help with musical activities. Ganschow et al. (1994, p. 199) and O'Brien Vance (2004, p. 30) also discuss selecting the instrument to suit the student. For example, if a student struggles with motor skills and has difficulty discerning 'left' from 'right' perhaps the trumpet is an appropriate choice as it involves fewer fingers and therefore lower fine motor skills than a flute or clarinet. Finally, multiple sources suggest working with a student individually wherever possible can be most beneficial because it allows the teacher to cater the lesson to the specific needs of that student (Heikkila & Knight, 2012, p. 55; Nelson, 2014, p. 188; O'Brien Vance, 2004, p. 29).

2.4 - Differences between adult and children learners

To assess whether techniques used on children can be applied to adult learners we must first understand the similarities and differences in the way the two age groups learn. For

the purpose of this study, an adult is considered to be any individual above 17 years of age. Kerka (2002) notes that several assertions about the characteristics of adult learners have been made:

> Adults need learning to be meaningful; they are autonomous, independent, and self-directed; prior experiences are a rich learning resource; their readiness to learn is associated with a transition point or a need to perform a task; their orientation is centered on problems, not content; they are intrinsically motivated; their participation in learning is voluntary. (p. 1)

In contrast, children are dependent learners, have limited experiences, are motivated by external rewards and punishments, are ready to learn based on age level, and are orientated to learn a particular subject matter (Kerka, 2002, p. 1).

In a study investigating the characteristics and experiences of teachers of adult music learners, Bowles (2010, p. 57) observed that when asked, 24% of teachers found changing learned habits or preconceived ideas was the most difficult aspect of teaching adult music learners. Twenty-three percent of participants also expressed a need for constant flexibility in lesson planning. This may pose a challenge for adult musicians with DD as opposed to child learners. Children have limited life experiences compared to adult learners, so it may be easier for children to adopt different methods of processing musical notation and thinking. Adult musicians with DD may rely heavily on musical notation for lack of a better method and may have to unlearn or rethink their approach to it.

2.4.1 - Working memory

Poor short-term memory appears to be a significant hurdle to adult musicians with DD (Weiss et al., 2014, p. 30). Weiss concluded that "rather than showing a discrepancy between enhanced sensitivity to non-speech sounds and reduced sensitivity to speech sounds, dyslexic musicians show a discrepancy between perceptual skills and working memory skills" (p. 30), suggesting that a lack of working memory skills may create a bottleneck on their ability and performance skills. Similar results were observed by Hébert et al. (2008, p. 379), in which the study showed that when presented with a basic repetition task, the performance of dyslexic participants worsened as the length of the activity increased (e.g. 8-note to 12-note passages). Interestingly, there appears to be little focus on improving memory in the literature pertaining to child learners, with a much more significant focus on improving phonological skills and timing deficits (Overy, 2003). A possible explanation for this is that prolonged study of music improves psychological and timing deficits and reveals other weak areas that are not as frequently addressed (such as poor working memory).

Chapter 3: A Review of Published Case Studies

This Chapter analyses and synthesises existing published case studies of adult professional musicians who identify as dyslexic and focuses on the coping methods and strategies employed by the individual musicians. The case studies in question are Ganschow et al. (1994), Nelson (2014), and Solook (2015). A basic summary of each is provided below.

"Dyslexia and Musical Notation" by Ganshow et al. (1994) has provided the basis for much of today's research on this topic and is commonly cited. The four authors provide six case studies of adult musicians, identifying each musician's strengths and weaknesses due to their dyslexia. They then synthesize the main compensatory strategies used by the musicians with other compensatory strategies documented in research regarding dyslexia in literacy.

Nelson's dissertation (2014) is a collection of five professional musicians' personal accounts of their strengths and weaknesses in their musical careers while dealing with dyslexia. Nelson synthesizes the data provided by the musicians and provides a list of strategies that the participants found helpful, and that can be applied to other musicians who experience dyslexia in music. A particular focus of the study was on the strategies used early in the participant's career so they could be applied by current school music students.

Solook's paper (2015) is an account of the author's journey as a musician with dysgraphia and dyslexia. Solook sought to understand how these learning difficulties affected their learning process and, over seven months, Solook studied four works with varying notation styles (traditional western art music notation and graphic notation), which were then

presented in a final recital.

Across the three case studies analysed, the participants expressed these common difficulties (Ganschow et al., 1994; Nelson, 2014; Solook, 2015):

- difficulties reading chords

- difficulties co-ordinating left and right hands

- poor memory

- difficulties with rhythm

- difficulties focusing on a heavily notated score (getting lost visually while reading notation)

- Low self-esteem

3.1 - Compensatory strategies used by the participants

3.1.1 - A tactile/kinesthetic approach (muscle memory)

Across all four of the published case studies analysed the most common compensatory method was to rely on muscle memory to lessen the need to re-read notation in-depth every time. Max, an orchestral brass player, stated that he would start with slowly learning the finger patterns and then increase the speed once the finger patterns were more comfortable (Nelson, 2014, p. 80). Max also stressed the importance of learning scales. Similarly, Danny learnt his music first by ear and then relied on the finger patterns to memorize his music (Nelson, 2014, p. 114). Likewise, in a study by Ganschow et al. (1994, pp. 191-193), participants RS and GT also relied on the muscle memory of piano chord positions. Participant ML (Ganschow et al., 1994, p. 193) found the tactile ability to place

their finger on the violin was most effective in memorising. Learning music by muscle memory does have flaws, however. Danny could not transpose easily as the finger patterns he learnt were key specific (Nelson, 2014, p. 114). Participant RS mentioned that if a passage was learnt incorrectly when it was initially memorised it could be very hard to unlearn (Ganschow et al., 1994, p. 191). Further, Max expressed that even though he relied on memorization to tackle difficult sections, he struggled with poor long-term memory and found that the act of memorizing large quantities of music difficult (Nelson, 2014, p. 178).

3.1.2 - Recordings and learning by ear

Like many non-dyslexic musicians, dyslexic musicians utilise recordings to make better sense of the written notation. Being able to hear a high-quality example of the sounds and effects one is aiming for allows a musician to better audiate their end goals (Hubicki & Miles, 1991). Participants Max, Stanley, and Danny (Nelson, 2014) and participants JL, GT, RS, and CL (Ganschow et al., 1994) all expressed some reliance on recordings to either partially or entirely learn passages by ear. Learning music by ear helps reduce one's reliance on notation but is not always an effective option, for example, when sight-reading or having to perform with short notice. Relying solely on recordings may also restrict a musician's interpretation of a piece as they will more likely imitate what is being heard rather than play what is notated. Musicians who learn by ear may learn the mistakes of others without noticing and may struggle to apply their own musical ideas and interpretations to a work as it is already provided to them by the recording. Memorising large quantities of information by ear may also lead to musicians forgetting a work after an extended period of time, recalling it incorrectly, or possibly combining and fusing it with another memorised work.

3.1.3 - Modifying/editing scores

Solook's (2015) dissertation documents his experiences with learning multiple styles of notation (traditional western notation and graphic notation) as a musician with dyslexia and dysgraphia. Solook's experiences with dysgraphia have led him to focus more on self-editing notation to make it easier to read rather than developing compensatory strategies as discussed above. Solook utilises colour to highlight specific information, similar to suggestions made by O'Brien Vance (2004) and Heikkila and Knight (2012). Solook (2015, p. 51) found that reducing the density of the information helped in making it easier to read and did so by enlarging scores, visually separating score instructions, for instance, moving dynamics further down below the staff so they are not confused with note heads, and separating voices and parts. To tackle difficult rhythms, Solook graphed out rhythms so the notation would be spaced to show its true rhythmic value, for example, a semi-breve (4 beats) would occupy a 2 cm space, a minim would occupy 1 cm (2 beats), a crotchet would occupy 0.5 cm (1 beat) and so on. By graphing the rhythms, the length at which it was supposed to be played could be not only be discerned by the symbol used but also by the space it occupied. Graphing the rhythms for multiple voices allowed Solook to see exactly how each part rhythmically aligned with the other.

3.1.4 - Viewing music holistically

Although people with dyslexia may struggle with traditional literacy-based learning they "often possess strengths in other areas such as the ability to think in pictures instead of words, being highly intuitive and insightful, having vivid imaginations, and being able to perceive multidimensionality" (Rolka & Silverman, 2015, p. 24). Multiple participants from

researched by both Ganschow et al. (1994) and Nelson (2014) described viewing music holistically or in an abstract way. Participant PM expressed that their "… image of music is not symbols on the page – it is a tangible structure in sound" and preferred to learn their piano music with both hands at the same time rather than learning each hand separately (Ganschow et al., 1994, p. 194). Stanley stated that he would learn a piece mostly by ear and just use the notes in front to provide a visual contour (Nelson, 2014, p. 148). Randy, a brass instrumentalist who participated in a marching band, found that the combination of sight, sound, and physical movement of the marching show made memorising music easier (Nelson, 2014, p. 134). Participant JL associated images with their music to provoke specific feelings and musical ideas (Ganschow et al., 1994, pp. 190-191). By departing from the idea that music is represented solely by notation on a page, dyslexic musicians can engage their minds in different ways to better understand music with non-traditional thought processes.

3.1.5 - Isolating musical components

Dyslexic musicians commonly find that heavily notated musical scores can be overwhelming and difficult to read. Breaking down and isolating specific musical components such as rhythm, pitch, and articulation has been suggested by multiple participants as a successful way to tackle complex notation. Max and Reggie (Nelson, 2014, pp. 178-180) found that by isolating components and working on each slowly they were able to focus solely on that component. This may be clapping out a rhythm, practicing articulation on one pitch to focus on clean tongue movement, or isolating the pitches from the rhythm and practicing just the intervals. Stanley (Nelson, 2014, p. 178) turned notes into musical flashcards that he would use to practice the notes without relation to the rhythm. Solook (2015, p. 51), a classical percussionist, would often isolate and graph out difficult rhythms to

practice away from the instrument, and found that separating voicing and parts made them easier to read when they were not all in one staff or line.

3.1.6 - Use of technology

Nelson (2014, pp. 177-178) observed that one of their study participants, Danny, a contemporary composer, relied heavily on technology to aid in his musical endeavours. Danny used recording devices and notation systems to make up for his shortcomings in reading notation and poor memory (which he suspected was caused by his dyslexia). Danny expressed that he never became proficient at reading or writing music and found it laborious. To combat this Danny used a Musical Instrument Digital Interface (MIDI) keyboard to play parts into a musical notation system where he could later edit, transpose, and layer parts together. Danny would often have a digital recorder on hand to record musical ideas or themes he wished to use later. Danny stated that his poor memory was often frustrating, especially if he had an idea for a musical line and was not able to record it to remember later.

3.2 - Conclusions and suggestions made by the authors

Although both Ganschow et al. (1994) and Nelson (2014) discuss techniques and strategies dyslexic musicians can use to ease the effects of dyslexia on music making, neither specifically address techniques that can be applied to mature musical concepts, but choose to focus on how these strategies may be applied to children's education. Both studies suggest multisensory learning as an effective way to teach music to dyslexic children. Nelson's (2014) observations of multisensory learning and teaching are similar to those found

elsewhere in the literature: by providing multisensory learning experiences a child's more dominant senses, for example, kinetic/tactile senses, can compensate for their weaker ones, for example, visual or aural senses. Ganschow et al. (1994, p. 198) advocate the use of the Coloured Staff system, a tangible score system that is focused on teaching notation to early beginners. Neither study presents a multisensory technique that applies specifically to adults other than the compensatory strategies used by the participants as discussed above.

Ganschow et al. (1994, p. 197) suggest a "do first; discuss later" approach in which incorporating aural aspects into lessons such as the use of the Kodály or Susuki methods may be beneficial to dyslexic learners. Ganschow et al. also discuss the importance of developing a student's sense of rhythm and time. Dyslexic students can often be overwhelmed by the large quantities of information provided on a musical score. Ganshow et al. suggest finding a method to clarify musical terminology present. For example, this may include using arrows and circles rather than words. The authors also suggest using images to convey information, for example drawing a key to remind one to notice a change in key signature. This method of clarifying musical terminology may be effective but is very personalized as what works for one musician may not work for another.

Nelson (2014, pp. 180-181) observes that participants Stanley and Danny had a strong connection to genres outside classical music. As genres such as jazz and popular music can typically be enjoyed without a strong ability to read musical notation, they may appeal more to dyslexic musicians. Danny expressed that if musical notation is a deterrent to young dyslexic musicians, popular music can provide a more enjoyable and fulfilling musical experience. If caught early in a student's musical development, a switch to jazz or popular music may be beneficial.

Nelson (2014, pp. 176-177) also discusses how alternatives to formal lessons, such as

an older student mentor, access to large ensembles, and/or encouraging small group/peer learning, could be beneficial to support a dyslexic student's musical education. Again, Nelson discusses small group and private instruction in the context of teaching children and does not address the implications for adult musicians. Adult musicians are more likely to receive one-on-one tuition. However, the frequency of these lessons is usually much lower than that of children learners. In contrast to a child's, an adult musician's musical advancement is mostly self-driven, requiring the musician to self-identify difficulties and find a way to best address them.

Finally, Ganshow et al. (1994, pp. 199-200) express the importance of distinguishing music from musical notation. The authors emphasise that you do not have to be a good music reader to be a good musician, and stress that support and encouragement is crucial when teaching dyslexic learners as they commonly suffer from poor self-esteem.

3.3 - Summary of techniques and suggestions found in the literature review and the review of published case studies

Table 1 presents a summary of techniques, strategies and suggestions found in the literature review and the review of published case studies completed in Chapters 2 and 3. Each technique has been assessed to see if it would be suitable for use by children or adult learners. Although many of the techniques work for both adults and children, some are not always appropriate for complex music making and exceptions have been noted in the table. To my knowledge this is the first collection of strategies that dyslexic musicians can use that addresses the difference between adult and child learners. I hope this table will provide an easily accessible resource for dyslexic musicians and their educators to consult.

Table 1

Summary of Techniques and Suggestions to Assist Dyslexic Musicians

Techniques, strategies, and suggestions	Applicable for teaching dyslexic children	Applicable for use by dyslexic adult musicians	Source	Reference in this text
Modifying scores				
- Enlarging scores	✓	✓	O'Brien Vance(2004)	2.3.1
			Heikkila (2012)	3.1.3
			Solook (2015)	
- Visually spacing parts and voicings	✓	✓	Solook (2015)	2.3.1
				3.1.3
- Using pastel coloured paper	✓	✓	O'Brien Vance (2004)	2.3.1
			Heikkila (2012)	
- Using colour (highlighting score instructions etc.)	✓	✓	O'Brien Vance (2004)	2.3.1
			Heikkila (2012)	3.1.3
			Solook (2015)	
- Use circles or lines to clarify musical terminology	✓	✓	Ganschow et al. (1994)	3.1.3
			Solook (2015)	
- Using drawings or images to represent score instructions	✓	✓	Ganschow et al. (1994)	3.2
			Solook (2015)	
- Editing stem directions	✓ - may be applied to teaching beginners	✗ - may not apply to complex music	Flach (2016)	2.3.1
Aural skills				
- Singing and playing along	✓	✓	O'Brien Vance (2004)	2.3.2
			Heikkila and Knight (2012)	
- Using recordings	✓	✓	Hubicki (1991)	2.3.2
			Ganschow et al. (1994)	3.1.2
			Nelson (2014)	
- Learning by ear	✓ - may be difficult for early beginners	✓	Ganschow et al. (1994)	3.1.2
			Nelson (2014)	

Techniques, strategies, and suggestions	Applicable for teaching dyslexic children	Applicable for use by dyslexic adult musicians	Source	Reference in this text
Rhythm and body movement				
- Graphing out difficult rhythms	✓ - may require assistance	✓	Solook (2015)	3.1.3
- Using the body during rhythm exercises	✓	✓	O'Brien Vance (2004)	2.3.3
- Isolating musical components (clapping rhythms, isolating intervals)	✓	✓	O'Brien Vance (2004) Nelson (2014) Solook (2015)	2.3.3 3.1.5
- Learn using muscle memory	✓ - may be difficult for beginners	✓	Ganschow et al. (1994) Nelson (2014)	3.1.1
Established methods				
- Coloured staff system	✓	✗ - does not apply to mature musical concepts	Hubicki and Miles (1991)	2.3.4
- Susuki method	✓	✓ - when studied at advanced levels	Ganschow et al. (1994)	3.2
- Kodály Method	✓	✓ - when studied at advance levels	Ganschow et al. (1994)	2.3.1
Technology				
- Use of tablets and apps for education	✓	✓ - depending on the complexity of the application	Witmer (2015)	2.3.5
- Use of recording devices	✓	✓	Nelson (2014)	3.1.6
- Use of notation programs and software	✓ - may require assistance	✓	Nelson (2014)	3.1.6

Techniques, strategies, and suggestions	Applicable for teaching dyslexic children	Applicable for use by dyslexic adult musicians	Source	Reference in this text
Environmental factors				
- Placement of student in the classroom	✓	✓/✗ - may not apply as adult learners have different classroom experiences	O'Brien Vance (2004)	2.3.6
- Instrument to suit the learner	✓ - if dealing with beginners and difficulties are identified early	✗ - may not apply as adults are not likely to change instruments	Ganschow et al. (1994) O'Brien Vance (2004)	2.3.6
- Frequent encouragement and feedback	✓	✓	O'Brien Vance (2004) Heikkila (2012)	2.3.6
- Asking the student to be specific in self-criticisms	✓	✓	O'Brien Vance (2004)	2.3.6
- Individual and/or small group instruction	✓	✓/✗ - adults rarely have group lessons	O'Brien Vance (2004) Heikkila (2012) Nelson (2014)	2.3.6
- Outside motivators	✓	✓	Solook (2015)	2.3.6
Other				
- Viewing music holistically	✓	✓	Ganschow et al. (1994) Nelson (2014)	3.1.4
- Assigning images to a work to provoke specific musical ideas	✓	✓	Ganschow et al. (1994)	3.1.4
- Learning jazz and popular music	✓	✓	Nelson (2014)	3.2
- Distinguishing music from musical notation	✓	✓	Ganschow et al. (1994)	3.2

Chapter 4: Use of Digital Media to Support Dyslexic Musicians

This Chapter explores how the techniques and suggestions discussed in Chapters 2 and 3 can be adapted and applied through a digital medium to ease the effects of dyslexia when reading musical notation. These adaptations have the potential to be combined into a digital application that could be specifically designed to assist adult dyslexic musicians to customize their scores to create a personalised, efficient, and effective way to read music, but may have a wider application for all music readers. The application could attempt to combine visual, aural, and kinetic senses to encourage multisensory learning, which have been demonstrated to be effective with dyslexic learners (Overy, 2003; Witmer, 2015). The proposed application would ideally be highly customisable to accommodate the different preferences and needs of each individual, because dyslexia can manifest differently from person to person. Images illustrating the key features and examples are used below to demonstrate concepts and possible adaptations that could be included in the proposed application. A minimum viable product was not created due to the limited time available in this study but is the obvious next step in the development of this idea.

4.1 - Methodology

Chapters 2 and 3 above present a synthesised collection of current knowledge around dyslexia and music learning in both adults and children (summarised in Section 3.3). Each technique or suggestion in this summary was assessed for suitability in assisting child or adult dyslexic learners.

I propose the development of a customisable music reading application specifically designed to assist dyslexic musicians that allows the application of these techniques through a digital medium. Features could include:

- Core features and functions designed to assist dyslexic musicians

  o Scrolling score feature

  o Rhythmically accurate note spacing

  o Coloured dynamic overlays

  o Breakdown feature - isolating musical components

  o Playback feature

- Customisable elements that may help optimise music reading

  o Adjustable background colour

  o Customisable symbol colours

  o Fonts and font size

  o Mood board tab

These features were assessed holistically with the following criteria in mind during conceptualisation:

- What problem or deficit does this adaptation address?

- If applicable, what technique or method has been modified/adapted to create the feature?

- How does the modified technique address the problem?

- Does this adaptation apply well to a digital medium?

- Does the new suggested method require extra learning?

- Are there any limitations related to the adaptation?

4.2 - Adaptations

4.2.1 - Scrolling score feature

Western music notation is traditionally read from left to right, similar to text reading in many European languages. This method of stacking lines of information one on top of the other can create a page dense with information. Solook (2015, p. 51), as well as many other dyslexic musicians, found that visually separating scores (increasing the space between systems) was an effective way to reduce being overwhelmed by the amount of information on the page. The use of a panoramic view or scrolling score may be an effective solution, and can be quicker than rewriting and separating music into a more spaced printed format (Figure 1: All figures in this document were created using *MuseScore* (Musescore BVBA, 2020) unless otherwise stated in the figure caption). A single continuous system of music could move from right to left across the screen as the piece progressed, allowing the musician to focus solely on the section being played. The scrolling score may reduce the possibility of getting lost in a page of music and encourages the musician to keep moving through the music. In addition, a scrolling score could encourage the reader to look forward, which may help dyslexic musicians who find their eyes lingering too long on a section of the score (Miles et al., 2008). The proposed application would allow users to switch between a standard paper view and the panorama view and would provide either a scrolling index function or a *find a bar* navigation tool to allow the musician to quickly move around the score when practising alone or in an ensemble.

Figure 1

The Scrolling Score Moving as Time Progresses
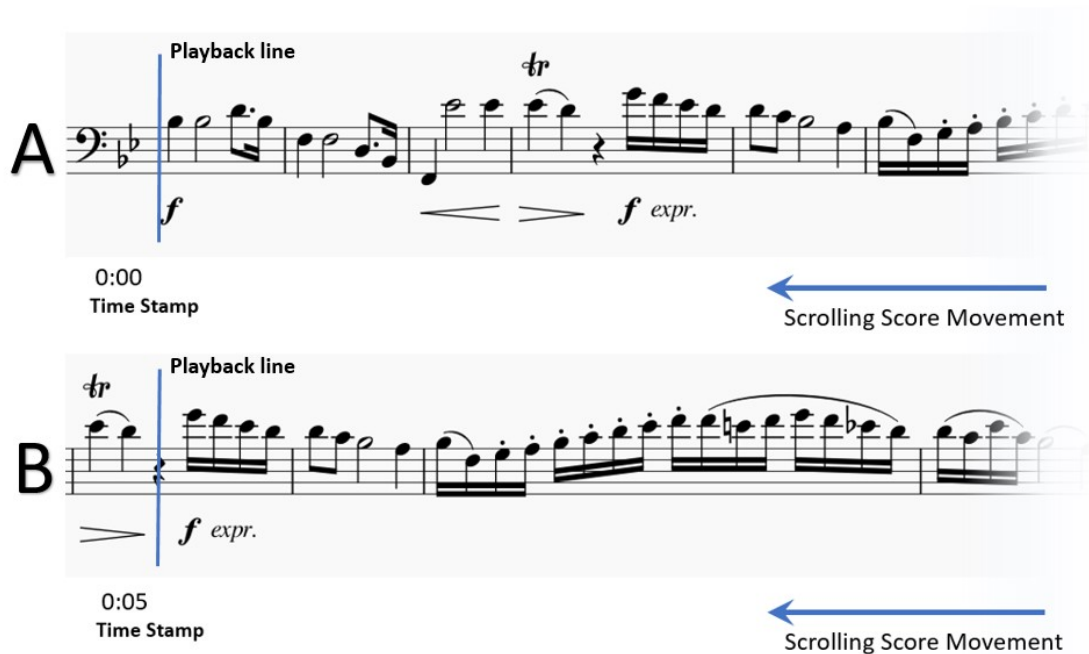
Note. **A**: The score at time stamp 0:00; **B**: The score at time stamp 0:05, demonstrating the score movement from right to left as the piece progresses. The musical example used in this figure is the first movement of Mozart's *Bassoon Concerto in F major.*

The scrolling score function would have multiple options for setting the tempo: single tempo, multiple tempos, a possible eye-tracking option, and a *listen and move* option. The single tempo option would allow a user to set a single tempo for the entire duration. This option may suit basic etudes and technical practice. The multiple tempo option would allow users to section up a work and set a tempo for each, possibly allowing basic *accelerandos* and *ritardandos* to be programmed in. The interface would allow musicians to set their own

tempo changes that could be edited to suit them, and the work being played. A third and more advanced option that utilizes eye-tracking technology could be integrated but more research is required to understand exactly how this could be applied. Finally, the listen and move option may involve a score that listens to the sounds being produced and moves along as they are played. This would link in with the playback feature further discussed in Section 4.2.5.

The scrolling score idea does have some limitations. Setting specific tempos may hinder musicality and artistic freedom. Unless a musician meticulously programmed every minor tempo variation into a work it may be hard to imitate the same flow of an organic performance. Prescribing a set tempo also limits spontaneity and possible improvisation. The listen and move option may also be ineffective if the musician makes a mistake or the audio is unclear and the application is unable to follow the musician's sound.

The scrolling score shows the most promise in the practicing of etudes, sight-reading, and in the early stages of learning a work. After becoming more comfortable with the work and its notation the musician can return to a standard paper score for the later stages of learning and for performances.

4.2.2 - Rhythmically accurate note spacing

Reading music contains an important spatial component as "reading proceeds both sequentially and simultaneously" requiring the reader to decode the vertical dimension (pitch) over time (Flach et al., 2016, p. 235). The mensural notation system is Western art music's most recognised notation system, in which the space between each note is decided by its rhythmic value and lines up relative to the beat it occupied within a bar (Figure 2). However, as music becomes more complex and printing and handwriting styles change from manuscript to manuscript, the notation can become distorted, and no longer spaced accurately to

represent the note's true rhythmic value (Figure 3). This can cause problems for dyslexic musicians because as the score becomes more dense, the reader can no longer discern a note's rhythmic value from its relative space in the bar and therefore must rely entirely on the symbol used to represent the rhythm. By providing a score that is correctly spaced, dyslexic musicians can discern the rhythmic value of a symbol by its rhythmic symbol and its relative length and position within the bar.

Figure 2

Mensural Notation Demonstrating Rhythmically Proportionate Note Spacing

Figure 3

An Example of Poor Note Spacing with Unclear Bar Lines and Crowded Notation

Note. Taken from Sloboda (1981)

When a score is uploaded into the proposed application, it would automatically take the symbols provided and space the notation to represent its true rhythmic value. However, the biggest concern with this function is that it may be laborious to input a score. The application would need to be able to recognise a scanned score and then re-represent the musical notation to be spatially accurate. If this is not possible, each score may have to be manually input, which could deter consumers as accessibility is therefore limited. As a score must be equally spaced, this function will allow the scrolling system to move at a consistent speed.

4.2.3 - Coloured dynamic overlays

As noted by Flach et al. (2016), "Using colour is a well-known phenomenon in music-reading research; however, it is mainly investigated in the context of beginning musicians"

(p. 236). In the proposed application, colour could be used to suit more mature musical concepts, unlike the coloured-in notes system (Rogers, 1991) and Hubicki and Miles's (1991) Coloured Staff system, which are primarily used for teaching early music learners.

Adding colour to a score is another way to remove the need for certain symbols while still retaining the information the symbol represents, encouraging multimodal learning. O'Brien Vance (2004) and Heikkila and Knight (2012) have suggested assigning a different colour to each dynamic to create a colourful musical road map for students to follow. Assigning a colour to a dynamic allows the musician to use the colour to discern the dynamic, negating the need to look for a dynamic marking. The proposed application's coloured dynamics feature would remove the dynamic symbols from the score and replace them with coloured shaded overlays, with a colour assigned to each dynamic. The user would have three options for display: standard dynamic notation (Figure 4, **A**); a shaded overlay that covers the entire staff (Figure 4, **B**); or a coloured bar that would be displayed underneath the staff (Figure 4, **C**). The user will be able to customise which colour is assigned to each dynamic and thereby avoid pre-set colours holding unwanted connotations. For example, one user may use red for a *forte* dynamic whereas another may use yellow for *forte* as the colour red may imply anger or a harsh tone to them. Removing the dynamic symbols and replacing them with coloured overlays may involve a learning curve, so an intermediate step may be required. This would entail retaining the dynamic symbols but instead colouring the text (Figure 5). The coloured dynamics feature would remove one more written component, reducing the number of symbols a reader must identify and decode, allowing the user to focus on other parts of the notation.

Figure 4

Options for Displaying Dynamics

Note. **A**: Standard use of dynamic notation; **B**: Shaded dynamic overlay; **C**: Coloured

dynamic bar. In this example, *piano* is represented by blue, *mezzo piano* by green, *mezzo*

forte by yellow, and *forte* by red.

Figure 5

Coloured Dynamic Symbols

4.2.4 - Breakdown feature – isolating musical concepts

Music notation can be dense with information, containing instructions for pitch, rhythm, articulation, and tempo. Multiple participants from the review of published case studies in Chapter 3 found that isolating musical concepts helped them focus on one element at a time, allowing them to later add the components back together more successfully (Nelson, 2014; Solook, 2015). The proposed application would contain a breakdown feature that would allow users to isolate musical components, assisting in learning one musical element at a time. For example, both dyslexic children and adults often demonstrate difficulties reading rhythm (Ganschow et al., 1994; O'Brien Vance, 2004). The proposed application could assist by separating the rhythm from the rest of the score components, such as pitch, by displaying only the rhythm (Figure 6). This allows the user to practice the rhythm in isolation without having to shift through other components of the score.

Figure 6

Isolating Rhythm Using the Breakdown Feature

Note: **A**: A section of music in its original form; **B**: The rhythm of the same passage isolated using the breakdown feature.

The breakdown feature could also be used to remove all dynamic, articulation, and expression markings so the musician could focus on just the pitch and rhythm components and not become overwhelmed. For example, if a musician was having trouble reading a large number of accidentals and was distracted by articulation markings, removing these markings allows them to focus only on the accidentals (Figure 7).

4.2.5 - Playback Feature

The playback feature is a staple of most music notation software, in which the program has a feature that will play what has been notated. The proposed application would contain a similar functioning playback feature that would play the notation on the page, providing an example of the sound for musician to learn from. Having an easily accessible audio example will provide musicians with rhythm and pitch to compare their playing against. Although the use of professional recordings is still encouraged, having a readily accessible playback feature would help a musician figure out a tricky rhythm or assist with pitching a difficult interval. A possible extension of this feature would be an immediate feedback function similar to the feedback feature of *SmartMusic (MakeMusic, 2019)*, that would listen and assess a musician's performance and provide instant feedback on pitch and rhythm.

Figure 7

Removing Distracting Markings Using the Breakdown Feature

Note. **A**: The original score with included articulation and dynamic markings; **B**: The same score with articulations and dynamic markings removed by the breakdown feature.

4.3 - Customisation features

Reading music is a different experience for all learners, especially those with learning difficulties such as dyslexia. Customising as many aspects of the reading process as possible allows a musician to improve the efficiency and effectiveness of their learning process, hopefully lessening the impact of reading difficulties on their learning experience.

4.3.1 - Adjustable background colour

It has been suggested by O'Brien Vance (2004) and Heikkila and Knight (2012) that printing music on pastel coloured paper may assist a student in reading as it reduces the contrast between the paper and the text on the page. The act of printing information on pastel paper has a similar effect to that of Irlen lenses, which are tinted coloured glasses one can

wear to lessen the effects of Irlen Syndrome - a visual perception disorder that can cause difficulties with reading, eye strain, and fatigue (Irlen Association). To minimise the effort for dyslexic readers, the proposed application would have a customisation feature allowing the user to adjust the contrast of text to the background by changing the background colour. Users would have access to a spectrum of colours to use as backgrounds as well as some pre-set colours such as pastel green, pastel yellow, lavender, light blue, and light grey (Figure 8).

Figure 8

Reduced Contrast Through Customisable Background Colours

Note. This musical example is the opening of Beethoven's *Moonlight Sonata No. 14,* first movement

4.3.2 - Customisable symbol colours

Colour has also been used to highlight notation to capture the reader's attention. The proposed application would allow the user to customise the colour of every element or symbol in the score. For example, if a user was having difficulty remembering to play an accidental they might colour it a bright colour to draw their attention to it (Figure 9). Another user may find that having all elements of a score in the same colour may cause them to blur together and be difficult to differentiate. To combat this, the user may set the notes to black but make staccatos and accents red, accidentals green, and slurs blue, to accentuate contrast (Figure 10). In this way a user can customize their reading experience with colour to best suit their reading needs.
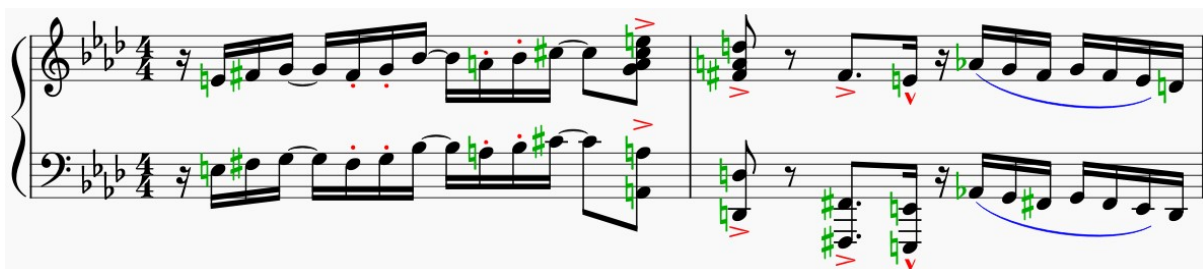
Figure 9

Using Colour to Highlight an Accidental

Figure 10

Customizing Symbol Colours

4.3.3 - Fonts and font size

A study by O'Brien et al. (2005) found that dyslexic students needed 32% larger font sizes to reach maximum text reading speeds when compared to non-dyslexic students. These findings by O'Brien et al. are in line with suggestions made by O'Brien Vance (2004), Heikkila and Knight (2012), and Solook (2015), in which they suggest enlarging scores (which will enlarge the font size) to aid dyslexic music readers. The proposed application would enable users to adjust the font size, allowing the user to pick a size that best suits their reading ability.

Special text fonts have been designed to assist dyslexic readers and there are musical fonts for dyslexic readers under development, but none of which is currently commercially available. If these fonts do become accessible, the proposed application would allow the user to change the font of the music similar to changing the font in a text document. This further adds to the ability to customise the user's reading experience.

The proposed application would also provide an annotations feature, which would allow users to draw and mark up a score similar to the way a musician would use a pencil to mark a paper score. The annotation feature could have adjustable pen size and colour to suit the user's needs.
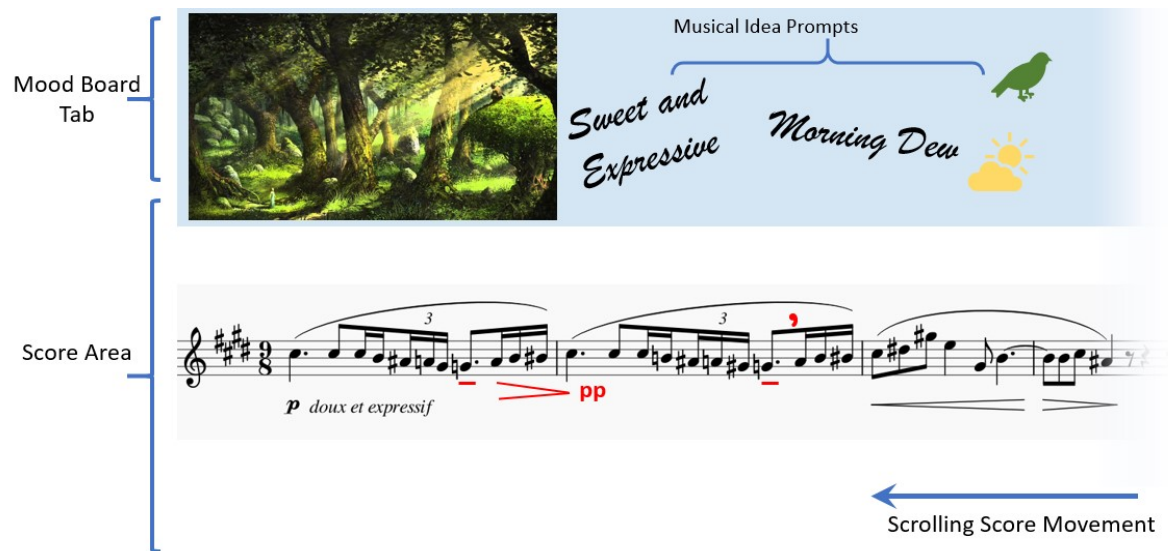
4.3.4 - Mood board

Dyslexic learners are often characterised by their ability to think differently when compared to non-dyslexic people, commonly displaying an ability to think in pictures instead of words and being able to perceive multi-dimensionally (Rolka & Silverman, 2015). The emotions and thoughts music can evoke may be difficult to express with language, commonly

resulting in musicians exploring images to better define and describe the feelings that music can express.

A *mood board* or *notes space* may help some dyslexic learners better visualise and internalise the intent of the music. The mood board tab would be a multimodal space that would allow dyslexic musicians to think holistically by providing image prompts to better express musical intention. This mood board feature would be a tab that would sit above the score where images, drawings, and notes could be placed to create a multimodal ideas space. The mood board would be linked to the scrolling score feature so that as the notation progressed across the screen so would the mood board, allowing the user to assign different ideas and images to different sections of the work as it progresses.

There are two main types of score markings musicians use to annotate their music. The first is basic score marking, which may include adding an accidental, circling a key change, notating a change in articulation, or adding in a dynamic marking. These basic score notations must be placed within the score as the annotation interacts with the musical symbols within the staff. The second type of score markings are musical idea prompts, which commonly include keywords, phrases, and possibly images that musicians use to encourage certain thoughts or musical ideas. Musical idea prompts are usually written above or around the score and may obscure notation within the staff. The mood board tab would provide a specific area for the musical idea prompts, moving them away from the score and leaving only the basic score markings on the staff (Figure 11). This would reduce the number of markings and symbols surrounding the musical notation making the score easier to read and would allow users to import images directly to a particular part of the score. The mood board tab could be minimised at will, allowing users to focus on just the score when required.

Figure 11

The Mood Board Feature

Note. This musical example is the opening flute solo from Debussy's *Prélude à l'après-midi d'un faune.* The mood board has been used to hold keywords and an image that represents the gentle start to the piece. The red markings in this figure are basic score annotations added by the musician.

The mood board feature would allow users to further customise their reading experience and encourage multimodal learning by the incorporation of images as musical prompts. By separating basic score markings from musical idea prompts, musicians can easily discern the type of marking and its meaning from its location on the screen.

Chapter 5: Discussion and Conclusion

Music educators and researchers have looked to music as a therapeutic learning tool to assist dyslexic children to further their literacy skills because the multisensory nature of music is especially effective in assisting dyslexic learners (Habib et al., 2016; Overy, 2003; Rolka & Silverman, 2015). Unfortunately, little study has been done to investigate the effects of dyslexia on music reading skills and music education. What research does exist focuses on assisting dyslexic children, often neglecting the difficulties faced by adult dyslexic musicians and mature music learners. This study has compiled information uncovered in a literature review and a review of published case studies to create a collection of techniques, strategies, and suggestions that may be employed by dyslexic musicians to overcome the difficulties caused by dyslexia (Section 3.3). To my knowledge, this study is the first to synthesise literature from studies in both adults and children to create a resource dyslexic musicians and their educators can consult to better understand how to manage the difficulties caused by dyslexia.

Chapter 4 suggests how the compiled techniques might be applied through a digital medium to create a customisable music reading experience that will assist dyslexic musicians of all ages and reading levels, through features such as the scrolling score feature, rhythmically accurate note spacing, coloured dynamic overlays, breakdown feature, and playback feature with customisable elements such as adjustable background colour, customizable symbol colours, specialised font types and sizes, and the use of a mood board. Each feature proposed in Chapter 4 was designed to incorporate multimodal learning to present dyslexic learners with a new way to approach reading music notation. If developed, an application of this nature could provide many benefits for not just dyslexic musicians but for all music readers.

Discussion

Adult musicians with learning difficulties such as dyslexia are often overlooked by researchers, as their prolonged study of music has allowed them to develop compensatory strategies that hide the severity of their disorder (Hubicki & Miles, 1991). Because of this, there are few studies that seek to understand the relationship between dyslexia and music reading in adults, and even fewer educational sources dyslexic adult musicians can turn to for assistance. This summary of techniques and methods provided (see Section 3.3) offers a starting point for dyslexic musicians in their journey to understand dyslexia and music and, in the meantime, provide them with strategies to lessen the adverse effects of dyslexia on their music reading skills.

This study has aimed to bridge the gap between the literature regarding dyslexic adults and children to find similarities in techniques that can be used to assist dyslexic musicians overcome the difficulties caused by dyslexia. Similarities are present in the difficulties experienced by both dyslexic children and adult dyslexic musicians, with the exception of poor working memory in adults (Overy, 2003; Weiss, Ahissar, & Granot, 2014). A possible explanation of this may be that the prolonged study of music diminishes musical deficits in adults that are more often exhibited by children. However, more study is needed to understand how dyslexic musicians develop over extended periods of time.

Multimodal learning experiences have been suggested not only for music education but for all education involving dyslexic children (Vincent, 2008). Smartphones and tablet computers have great capacity to provide multimodal education, as discussed by Vincent (2008) and Witmer (2015), and are becoming a common staple in classrooms. Unfortunately, the focus of the majority of the literature on this topic is on how multimodal applications can assist in the education of children and does not address how multimodal media can assist

adult learners. For example, *Muzik Mystro* (Liu, 2020) is an app designed to make music notation more accessible to dyslexic musicians and uses a similar system to Rogers' (1991) colour-coded notation. Unfortunately, *Muzik Mystro* is aimed at teaching music notation to beginners and does not hold much promise for use with high-level music making or complex scores.

The concepts and adaptations discussed in Chapter 4 above hold promise for the creation of an application that would provide a customisable reading experience for every musician. More research and development are needed before this application can be completed. The basic core features discussed in this study form a basis on which this application could be built. The concepts and adaptations in Chapter 4 are suggestions only and will require testing to evaluate their validity and effectiveness. By utilizing the flexibility of tablet computers and smartphones, an application of this nature would combine visual, aural, and kinetic senses encouraging multisensory learning that has shown promise in the education of dyslexic children (Overy, 2003; Witmer, 2015).

Further studies should inquire into the development of specific digital musical fonts and the usefulness of such an application for dyslexic learners, particularly adults. Studies have been undertaken that demonstrate the importance of fonts in educational material (French et al., 2013), and it has been shown that fonts designed specifically for people with dyslexia, such as *EasyReading*, can be considered a compensatory tool to ease their reading experiences (Bachmann & Mengheri, 2018). Unfortunately, no dyslexia-specific musical fonts are commercially available.

As this study is focused on literature from the music sub-discipline, it does not address the neurobiological understanding of developmental dyslexia and its relationship with music. A review by Kearns et al. (2019) discusses the current understanding of dyslexia and

reading abilities, stating the primary difference between individuals with dyslexia and those without is that those with dyslexia show less activation in the temporoparietal and occipitotemporal regions of the brain during reading tasks. Kearns et al. go on to state that readers with dyslexia not only show less activation overall, but show a different pattern of activation, implying that readers with dyslexia work differently. This result supports the techniques suggested in this study, which utilise alternative learning pathways that may assist dyslexic musicians. There are few studies that examine the neurobiological aspects of dyslexia in relation to music. Those that do, focus on how music can be used as a therapeutic tool to improve literacy in dyslexic children (Tzipi Horowitz & Breznitz, 2009). More study is required to examine the effect of specifically designed music reading interventions on musicians with dyslexia, possibly investigating how a dyslexic musician's learning pathways develop from youth to adulthood.

As noted in Chapter 4, eye-tracking technology has the potential to be integrated into the proposed application as part of the scrolling score feature. A recent study by Franzen et al. (2020) that examines the visual reading strategies of dyslexic individuals when reading text concluded that individuals with dyslexia exhibited different eye movement patterns when reading, suggesting unique thought pathways are engaged when reading. This again supports the premise that people with dyslexia have a different thought process and may benefit from non-standard learning experiences. Research has been done that examines the eye tracking of musicians reading music (Drai-Zerbib, Baccino, & Bigand, 2012; Madell & Héébert, 2008). To my knowledge, there has been no study that has assessed if there is a difference in eye movements between dyslexic and non-dyslexic musicians. Further research is needed to better understand how dyslexic readers' eyes move while reading music, which could contribute to our understanding of why dyslexic readers may have difficulties sight-reading.

Conclusion

The insights in Chapter 3 of this study, previously not assembled in one place, supply dyslexic musicians and their educators with practical suggestions and techniques to begin to overcome the challenges dyslexia can pose in musical endeavours. Multisensory and multimodal learning has become increasingly accessible to today's musicians through the popular use of tablets and smartphones, offering many beneficial possibilities to improve the learning and reading experiences of dyslexic musicians. This study has taken a first step towards conceptualising a customisable music reading application that would utilise the multimodal nature of tablet computers and smartphones to suit the learning styles of dyslexic musicians.

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