Exploring the Phenomenon of Dysmusia in Young Piano Students

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Abstract

Music reading is an essential yet difficult skill, one with which many students and professionals alike struggle (Sloboda, 1974; Gromko, 2004; Pike & Carter, 2010). It is a complex task requiring the processing of many skills including cognitive as well as perceptual and motor processes through reacting to stimuli (Jensen, 2016). Unsuccessful attainment of music reading proficiency leads to frustration and often results in lesson abandonment in the early years of instruction (Gordon, 2000; Brand, 2001). In the pedagogical community, it has been said that students vary widely in their progress towards fluent reading (Mills and McPherson, 2006). Meanwhile, those at the professional level with music reading difficulties feel like it is an obstacle they regularly face in their careers. While many causes have been suggested for music reading difficulties, over the past few decades, it has been suggested that dysmusia (also known as musical dyslexia) might be a cause of these music reading difficulties (Cuddy & Hébert, 2006; Gordon, 2000). The current dissertation explored dysmusia in musicians, particularly young piano students, in the form of four articles. The first article reviewed accounts of dysmusia in musicians to organize manifestations (clusters of difficulties) and indicators (specific difficulties). Four manifestations found comprised music reading, music writing, sequencing, and skills. Musician accounts suggested dysmusia shares auditory, processing speed, motor, visual, and memory deficits with dyslexia. For the most part, literature surrounded pianists. The second article reviewed tests to quantitatively measure dysmusia, and found a gap in testing for music reading and writing in particular. Writing tests were developed to match the existing music reading tests in our laboratory on 1-note, 2-note, and 3-note stimuli. Auditory skills may be sensitive to music reading expertise according to the literature. Article three sought to generate baseline data for music reading and music writing tests, as well as for audiation, in a population

of young piano students with neither dyslexia nor suspected dysmusia. Furthermore, given the relationships between text reading and writing, and text reading and auditory skills, article three compared music reading to writing on paired conditions, and music sight-reading to audiation (for tonal, rhythm, and composite parameters). Results provided baseline data for music reading, writing, and audiation tests in both beginner and intermediate-advanced students. For music reading to writing, tasks are comparably difficult for 1-note conditions, but as the tasks increase, writing performance is superior to reading. While audiation performance is not affected by sight-reading proficiency in a statistically significant way, there are some visual differences that indicate within our participant sample, there was some affect of expertise on tonal performance and not for rhythm. Article four concerns the case of EA, a 10-year-old piano student with dyslexia. While EA demonstrated music reading difficulties early in her musical training, she currently demonstrates average to superior music reading ability according to her parent, piano teacher, and most recent Conservatory Canada exam. Interview findings reveal that EA has significant family involvement in her music learning, and she has a positive attitude towards learning, which may have impacted her test performance. While a test for processing speed confirmed EA’s deficit associated with her dyslexia diagnosis, she neither demonstrated a deficit in motor skills as measured by a pegboard test nor in her music test performance. EA scored slightly lower than matched controls in 1-note identification and 2-note pattern playing, which was less than 1 SD before the mean. Her superior performance in music writing tasks including copying and dictation with 1, 2, and 3 notes is in contrast to her dysgraphia for letter writing. Specific to music sight-reading, EA made more rhythm mistakes than matched controls, though she played most of the pitches correctly. Finally, her audiation percentile ranks were about average, and within the same ranges as matched controls, with a comparatively stronger performance on the rhythm parameter, and weaker performance on the tonal parameter. The four articles of the dissertation combine to explore what dysmusia could be, and how it could be measured, while considering that dysmusia could appear differently depending on the individual. Furthermore, the case study results from article four are evidence that not all individuals with dyslexia have dysmusia, and that dysmusia may be a domain specific condition as posited by Cuddy & Hébert (2006).

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Statement of Contribution

I, Meganne Woronchak, was primarily responsible for the research program of this dissertation, which included the conceptualization, literature review, participant recruitment, data collection, data analysis, and writing. As such, I am the first author on all four articles presented in the dissertation. My supervisor, Dr. Gilles Comeau, provided conceptual input, feedback, and guidance for every part of this dissertation. As such, he is the coauthor on all four articles. My thesis advisory committee consisted of Dr. Donald Russell and Dr. Heidi Sveistrup. Both individuals provided invaluable feedback at my thesis proposal defence and periodically throughout data analysis, particularly for article three. Mikael Swirp collected quantitative data for article four in the capacity of research assistant. Though I carried out data analysis on my own, I consulted Dr. Allison Clouthier, Teri Slade, Mikael Swirp, Zoë Sayle, and Mathieu Fortier for advice. In early stages of developing music writing tests discussed in articles two through four, Teofana Iacob and Kim Ng served as research assistants in brainstorming and pilot testing. Finally, Jeffrey Sabo contributed by coding interview transcripts to act as my inter-rater agreement researcher for article four.

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“We could change this whole world with a piano.” – Ed Sheeran

General Introduction

From beginner to professional musicians, music reading is an area in which several individuals struggle (Sloboda, 1974; Gromko, 2004; Pike & Carter, 2010). While reacting to stimuli, several complex skills are processed in the cognitive, perceptual, and motor domains (Jensen, 2016). When musicians face unsuccessful attainment of music reading proficiency, the resulting frustration often concludes with abandonment of music study (Gordon, 2000; Brand, 2001). Piano teachers report that there is significant variance in student progress towards fluent reading (Mills and McPherson, 2006). Professional musicians also describe experiences with music reading difficulties that impact their professional careers. Many testimonials exist on this topic both in the realm of classical and popular music domains. For example, Backhouse (2001) interviewed an adult classical pianist who, despite her musical career, felt continual stress while learning and memorizing new repertoire because of music reading difficulties. Nelson (2014) interviewed a popular music composer who felt compelled to composition instead of classical performance because it did not require a strong proficiency in music reading. Moreover, he rejected participating in the high school band in part out of a fear of reading music.

While many causes have been suggested for music reading difficulties, over the past few decades, it has been suggested that musical dyslexia might be a cause (Cuddy & Hébert, 2006; Gordon, 2000). Cuddy and Hébert (2006) related their definition of musical dyslexia to text dyslexia. They defined musical dyslexia as “difficulty with learning to read music despite normal intelligence and opportunities [which] should be identifiable and should exist as an entity separate from text dyslexia” (p. 203).[1] In an editorial, Gordon (2000) introduced the term

[1] “Text dyslexia, similarly defined as a difficulty with learning to read despite normal intelligence and opportunities, is a well-recognized problem and has stimulated much research in past decades” (Cuddy & Hébert 2006, p. 203).

dysmusia as an alternate way to name musical dyslexia. For clarity, we will use the term dysmusia going forward in this document. In pedagogical and informal literature, there are many examples of what dysmusia could look like. Two particular books are well-known in the field. The first book, *Music and Dyslexia: Opening New Doors* (Miles & Westcombe, 2001) contains four chapters on individuals with dyslexia who are learning music and four chapters on musicians' testimonies. For example, Ditchfield contributes a chapter about teaching piano to a dyslexic six-year-old, who demonstrated at the lesson: a short concentration span compared to peers of the same age, a short-term memory of recently played notes, difficulty in note-name identification, slower progress in learning and securing new pieces compared to peers, more frequent hand switching compared to peers, and comparable intelligence to peers. The second book, *Music and Dyslexia: A Positive Approach* (Miles, Westcombe, & Ditchfield, 2008), contains nine chapters on individuals with dyslexia who are learning music and three chapters on musicians' testimonies. For example, Lea contributes a chapter about his reflections regarding his dyslexia impacting his ability to sight-read guitar music and his ability to memorize cello music. There are multiple informal reports in music teacher journals and magazines. For example, in an article of International Musician (2010), singer-songwriter Edwin McCain comments that despite his choral training and piano lessons, he never successfully learned to read music with his diagnosis of dyslexia and found inspiration learning the guitar by ear. In an article of American Music Teacher, Johnson (2016) reflects on teaching many piano students who she thought possibly had dyslexia because of an increased prevalence of music reading mistakes compared to peers: third transpositions, discriminating between high and low pitches, discriminating between left and right hands, and difficulty in pattern recognition of ascending and descending notes. In an editorial, Gordon (2000) writes about dysmusia and provides two anecdotes of piano students who displayed musical abilities but struggled only with music reading. First, he references a 10-year-old boy with exceptional performance skills who learns by ear because reading music is difficult. Second, he references a 12-year-old student with four years of training who perceives music notation as “a lot of meaningless dots with no real pattern to them” (p. 214).

There is some scholarly literature about the relationship between music and dyslexia, but little scholarly literature regarding dysmusia without reference to dyslexia. There is one empirical case study by Cuddy and Hébert (2006) on dysmusia (referred to in the paper as developmental musical dyslexia) with musical testing and not language testing. The relationship between music and dyslexia has been the focus of two systematic reviews (Rolka & Silverman, 2015; Cogo-Moreira et al., 2012). Both found that music training is often used as a remedial tool for dyslexic individuals, but the absence of randomized control trials renders it impossible to make a judgement about the effectiveness of music training on text reading ability. Additionally, the influence of dyslexia on music learning and performance has been studied by various groups (Weiss, Granot, & Ahissar, 2014; Nelson, 2014; Nelson & Hourigan, 2016; Vladikovic, 2013; Ganschow, Lloyd-Jones, & Miles, 1994). The first article of this dissertation organizes the manifestations and indicators of dysmusia discussed in the broader musical population so as to develop understanding of how it presents in musicians varying in age, experience, and musical instrument type.

While article one showed that manifestations of dysmusia concern music reading, music writing, music listening, general cognitive skills, motor skills, and visual-spatial skills, much of the existing literature comprised qualitative studies and pedagogical reports. It appeared that the most difficulties were reported among pianists, and teachers and students alike reported frustration in the process of developing music reading acquisition in children. Therefore, the second through fourth articles of this dissertation explore how the manifestations and indicators of dysmusia can be quantifiably measured in a population of children learning piano. Article two proposes quantitative tests that could account for all the manifestations and indicators of dysmusia in the target population of children learning piano. While music reading tests are present in the literature, few are specific to piano as well as to children. We selected an in-house music reading battery developed at our laboratory. No tests for music writing are present in the literature, thus we developed copying and dictation tests based on research in dyslexia (Re & Cornoldi, 2015) using the same 1-note, 2-notes, and 3-notes stimuli as the music reading tests. For auditory skills, tests were more commonly available in the literature. We selected a commonly administered audiation test known to be inclusive to children with learning disabilities (Gordon, 2001). Tests for cognitive abilities and motor skills were considered especially for their administration feasibility, as pedagogy researchers furthering dysmusia research would be using the same materials and protocols. Considering findings of article one, which suggest that music reading, music writing, and auditory discrimination difficulties are common among musicians with dysmusia, the third article of the dissertation serves to create a baseline for test performance in young piano students without dysmusia, to which future studies can add to, and to which studies can compare cases of suspected dysmusia. In reading literature, from which dysmusia literature arose, there are known links between reading and writing performance in cases with and without dyslexia (Ray et al., 2021; Snowling, 2013; Snowling et al., 2018) and links between reading and auditory skills (Abramson & Lloyd, 2016; Lukács et al., 2021; Witton, Swoboda, Shapiro, & Talcott, 2020). However, these may be impacted by musical expertise, as not all musicians with dyslexia report challenges with auditory skills. We found, as predicted, mean test performance improves with musical playing expertise, with more accurate audiation performances in advanced participants compared to beginners. For music reading to writing comparisons, we found that decoding is significantly more difficult than writing, no matter the writing format (copying or dictation). For audiation, we found that musical expertise likely played a role in tonal performance, as participants with higher sight-reading proficiency had higher percentile rank scores compared to participants with lower sight-reading proficiency. However, this was not true for rhythm performance, with which both groups had varied scores. Our findings lead us to develop a case study in the fourth article of a child with a dyslexia diagnosis learning piano. In this article we compare her music reading, writing, and audiation scores to age matched controls from article three, as well as compare her processing speed and motor skills to normalized data. We synthesize the test performance data with qualitative interviews to contextualize her results within the environment in which she is learning music. Literature of musicians with dyslexia supports exploring both the quantitative test performance and qualitative aspects surrounding the case (Ashcroft, 2019; Du Toit, 2013; Hébert et al., 2008; Ganschow, Lloyd-Jones, & Miles, 1994; Nelson, 2014; Vladikovic, 2013).

Position on Definition of "Music Reading"

For the purposes of this dissertation, music reading is compared to text reading, though it is acknowledged that the two skills are not identical. In the first article, presented in Chapter 2, musicians with dyslexia identified difficulties with both identifying notes verbally as well as with decoding the notes at their instrument (interpreting the notes on the score to a motor action). Thus, these were the two types of music reading that were selected for measurement in the second, third, and fourth articles. Music reading at an instrument has a motor component that separates it from text reading aloud. We considered that in text reading and writing, there are studies in which participants responded to visual stimuli by typing on a computer keyboard, which has a shared motor component to music reading (Mayer et al., 2020; Ouellette & Tims, 2014; Renneberg & Torrance, 2017). However, the motor skills required to play an instrument require attention to technique, expression, duration, and velocity, none of which are required to type on a computer keyboard. Moreover, music reading studies with respect to motor skills have a focus on eye-hand span (Furneaux & Land, 1999; Sloboda, 1974, 1976, 1977, 1978; Truitt et al., 1997), and eye fixation patterns (Chang, 1993; Comeau, 2014; Drai-Zerbib, Baccino, & Bigand, 2012; Gilman, 2000; Goolsby 1994a, 1994b; Kinsler & Carpenter, 1995; Waters & Underwood, 1998). Given that the state of dysmusia research concerns the types of difficulties made by musicians, using eye-tracking technologies is out of the current project scope.

Chapter 1: Review of Literature

This chapter outlines the state of the literature around topics of music and dyslexia to situate the research purposes of this dissertation. The three sections of the review represent the main areas of research from largest to smallest, revealing the gap in the literature specific to challenges in music learning that could be faced by individuals with dyslexia. While the position taken throughout this dissertation is that dysmusia is related to dyslexia but may have its own identifiable criteria, it is built on research with individuals with dyslexia. Chapter 1 concludes with the overall research purposes and organizational summary of the dissertation.

Intersections of music and dyslexia scholarship have intrigued researchers since the 1970s, when it was first proposed that individuals with dyslexia possessed an auditory processing speed deficit (Tallal & Piercy, 1973). With the work of psychologist and cellist Tim Miles in the 1990s and 2000s, along with his colleagues at the British Dyslexia Association (BDA), the role music can play in individuals with dyslexia reached a broader pedagogical audience (Ganschow, Llyod-Jones, & Miles, 1994). According to Rolka and Silverman (2015), existing studies concerning music and dyslexia can be categorized in three groups: music training as an intervention for individuals with dyslexia, music tests as a means to assess brain function in individuals with dyslexia, and investigating which aspects of music learning could be challenging for individuals with dyslexia. This review encompasses studies from all three groups, and it will become evident that the largest gap in the research concerns music learning for individuals with dyslexia.

Music Training as an Intervention

Music training is used in interventions for individuals with dyslexia because dyslexia is hypothesized to include an auditory processing deficit (Tallal & Piercy, 1973), although this has been recently contested (Snowling, Gooch, McArthur, and Hulme, 2018). Music training as an intervention is a topic of interest based on studies exploring whether there are differences on test performance between individuals with and without dyslexia (Benson et al., 1997; Dellatolas et al., 2008; Grube et al., 2014; Huss et al., 2011; Overy, 2000; Overy, 2003; Overy, Meyler & Breznitz 2005; Murphy-Ruiz et al., 2013; Nicholson, Fawcett, & Clarke et al., 2003; Przybylski et al., 2013; Thomposn et al., 2006; Thomson & Goswami, 2008; Wolf, 2002; Ziegler et al., 2012). Then, a group of studies test children on auditory discrimination tasks following music training (Flaugnacco et al., 2014; Forgeard et al., 2008; Frey et al., 2019; Goswami et al., 2013; Leong & Goswami, 2014; Register, Darrow, Standler, & Swedberg, 2007; Zuk et al., 2017). The music tests used in these studies are largely unavailable for replication, but some research contains auditory test that are for public use.

Differences Between Children with and without Dyslexia. Through the consideration of Tallal and Piecy's early work (1973), they do not make the distinction of dyslexia, rather, they refer to their experimental group as having "developmental aphasia" which is another language disorder. Their group of participants with aphasia (*n* = 12) were matched to a control group for age, sex, and non-verbal intelligence. With headphones, participants listened to synthesized two-tone sequences and indicated whether they were the same or different and the response time was recorded as well as accuracy. The experimental group was significantly slower in their response time compared to the controls, though both groups achieved similar accuracy. Later, Tallal and Gaab (2006) reviewed literature comparing children with specific language learning impairments (a category in which dyslexia is included) to controls with musical training as a factor. They found that music training and aptitude (neither were specifically defined) improved the following areas in the language domain: reading, phonological awareness, pitch processing in speech, prosody perception, verbal memory, and verbal fluency. In the music domain, improvements included the processing of: melody, rhythm, metre, timbre, harmony, and contour. Shared by both language and music, music training improved the general processing of pitch discrimination, pitch memory, and rapid spectrotemporal processing.

Overy, Nicholson, Fawcett, and Clarke (2003) designed the *Musical Aptitude Tests* (MATs) to measure musical timing and pitch in children with and without dyslexia. The tests were based on the theory that individuals with dyslexia have a timing deficit, and hypothesized that that music tests with rhythm tasks could highlight this area. Their tests contained several aspects of rhythm and pitch, including rhythm and metre skills with and without reference to a given tempo (copying, discrimination), pitch skills (indicating number of pitches heard, discrimination of pitches, melodies, and timbres, and short melody singing). In their study with 15 children with dyslexia and 11 controls, their results supported the claim that children with dyslexia likely struggle with musical timing skills. However, the children with dyslexia performed better than controls on three of the pitch tasks, including pitch discrimination. The authors attributed this finding to greater musical experience in the group with dyslexia. Among the participants in the group with dyslexia, there was a subgroup for which the auditory processing tests were more difficult, which is explained by the differences in difficulties experienced by individuals with dyslexia. Since the publication of the MATs, they have not been replicated in published research.

In the study by Grube and colleagues (2014) which explored auditory processing in adolescents with (n = 28) and without dyslexia (n = 173), they used a component of the *Montreal Battery for the Evaluation of Amusia* (MBEA) (Peretz et al., 2013) among their in-house tests for auditory processing. The component chosen for the study was key violation, in which participants indicated if two melodies were the same or different based on presence of a note that violated the key structure. Grube and colleagues did not find any significant differences between adolescents with and without dyslexia, neither on the MBEA nor on their own tests. The MBEA continues to be used in studies of children suspected of having amusia (a pitch discrimination disorder) (Henry & McAuley, 2012; Nunes-Silva & Hasse, 2012; Pfeifer & Mamann, 2015; Vuvan et al., 2018), as well as in children with cochlear implants (Cooper, Tobey, & Loizou, 2008), but it has not been used in further studies of children with dyslexia.

Uniquely, Bishop-Liebler and colleagues (2014) explored differences between adult musicians with (n = 25) and without (n = 22) dyslexia, and non-musicians with dyslexia (n = 21) on auditory processing tests. The auditory tests included in the study were developed in their laboratory, concerning discrimination of amplitude, intensity, frequency, and duration. The tests followed what the authors referred to as a 'Dinosaur' estimation program, wherein each trial contains three stimuli: melody A, comparison melody X, and melody B. The results showed that musicians with dyslexia performed similarly to the musicians without dyslexia on all the auditory tests. Furthermore, the musicians with dyslexia performed significantly better than the non-musicians with dyslexia on some conditions of each test. The authors suggested that the superior performance of the musician groups compared to the non-musician group is attributable to enhanced auditory sensitivity from musical training.

Intervention Studies. Laboratory studies for assessing auditory perception in students following a musical intervention often use pitch and rhythm test paradigms developed by the research groups. For example, in the work of Leong and Goswami (2014), in which groups of adults with and without dyslexia followed a rhythmic entrainment program (beat tapping) during one session, the assessment tool measured amplitude modulation patterns of inter-tap intervals, vowel onset, and distance from each tap to vowel onset. The results were that the group with dyslexia demonstrated atypical beat tapping patterns, which was interpreted to mean that rhythmic perception could be a part of difficulties in phonological processing with respect to text reading. However, in the work of Forgeard and colleagues (2008), music lessons are used as the intervention, rather than entrainment exercises. Their article is divided into four separate experiments. In studies 1 and 2, a baseline was created by providing either music lessons or no music lessons to 44 children without dyslexia over a period of 20 and 31 months, with the pre- and post-testing including both music and literacy tests. Studies 3 and 4 included populations of children with dyslexia (31 and 5) to compare to the baseline data. The musical assessment test was Gordon's *Intermediate Measures of Music Audiation* (IMMA) (Gordon, 2001), which included parameters for auditory and rhythm discrimination. Combined, the studies suggested that there is a strong relationship between musical discrimination abilities and language skills in children. For children without dyslexia, melodic discrimination predicted phonological performance, and rhythm discrimination predicted reading skills. For children with dyslexia, musical training improved performance in reading abilities.

Music Tests to Assess Brain Function

Research examining brain imaging data in populations of children with and without dyslexia include several types of imaging techniques (Fried et al., 1981; Overy et al, 2004; Perrachione et al., 2014; Serrallach et al., 2014). The types of music tests used in brain function tests tend to be simple discrimination (indicating same or different) as this task can be achieved with a button press while being connected to the technology.

Electroencephalogram (EEG) and Event-Related Potentials (ERPs). EEGs collect electrical signals from the scalp. ERPs reflect cognitive processes in the "so called time domain"

(Hermann, Rach, Vosskuhl, & Strüber, 2014, p. 438). ERPs are calculated by taking the average of EEG across several trials. One refers to ERPs as positive or negative deflections based on how the deflections respond to manipulated cognitive and sensory processes. The results of ERPs are described with reference to frequency ranges. The limitation of using EEG to collect ERPs are in the quality of spatial resolution as well as its localization ability (Bandettini, 2020).

Fried and colleagues (1981) collected data from 13 boys (ages 8 to 12) with dyslexia to matched controls using ERPs. Among the participant group with dyslexia, the authors noted which individuals had an auditory processing deficit and which had a visual-spatial processing deficit. Electrodes were placed on select locations on left and right sides of the head, as well as on the forehead. Participants listened to chords and words. While the musical stimuli activated the right hemisphere of the brain significantly more than left in nearly all children without dyslexia, this was only the case for about half of the children with dyslexia – the subgroup with the visual-spatial processing deficit. The authors described those individuals with dyslexia with a visual-spatial deficit struggle with grapheme to phoneme rules in language, a process which occurs in the left hemisphere of the brain. Thus, individuals with the visual-spatial processing deficit may not have a fully developed capacity to process auditory information in the right hemisphere. The authors cautioned that they did not control for attentional differences among their participants.

Functional Magnetic Resource Imaging (fMRI). fMRI technology explores both spatial and temporal domains at the systems level of the brain (Bandettini, 2020). Specifically, fMRI can detect and map “localized cerebral hemodynamic changes that occur at the location of the increased brain activity [which] include blood, flow, volume, and oxygenation” (p. 24). Five advantages that fMRI has over other technologies include worldwide availability, noninvasiveness, higher spatial resolution and frequency compared to other scanners, scanning speed, and efficiency as it can create functional maps within minutes.

Overy and colleagues (2004) used fMRI to examine how 33 children 5 to 7 years old with and without dyslexia discriminated short melodies and rhythms. Participants used a button press response to indicate same or different. The melody tasks incorporated the first five pitches of the C major scale in the timbre of a marimba and all pitches had the same duration. To minimize confusion with the testing environment with the scanner, all participants completed a practice session a week prior to the study, though the average performances were similar on both sessions. The rhythm tasks had varied durations though stimuli used a consistent pitch. When the analysis was focused on the superior temporal gyrus, the authors found that melodic processing activated a larger area compared to rhythm processing. However, this difference was not found when the analysis was broadened to the auditory cortex. Activation patterns in the brain for both melody and rhythm discrimination tasks were similar in both groups of children, and the authors suggested that differences might develop in later childhood, as there are different activation patterns in adults compared to children.

Magnetic Resource Imaging (MRI) and Magnetoencephalography (MEG). MRI technology produces three-dimensional images by detecting changes in directions of protons as they rotate. Recently, MRI has developed to create a four-dimensional picture with the additional capability to measure complex blood flow patterns (Markl et al., 2012). Present day MEG technology uses helmets equipped with at least 300 sensors to cover a larger area of the head than in previous iterations which did not include the helmet (Bandettini, 2020).

Serrallach and colleagues (2014) used MRI and MEG to explore differences in children with dyslexia (*n* = 37), attention deficit disorder (ADD) (*n* = 36), and attention hyper-deficit disorder (ADHD) (*n* = 37) compared to controls (*n* = 37) with respect to psychoacoustic tests. While watching a silent movie, children passively listened to sounds comprising a variety of timbres (piano, trumpet, flute, clarinet, plucked violin, bass, and timpani) and complex harmonic tones (synthetically generated). Another task included the same auditory discrimination tasks used by Huss and colleagues (2011). The results showed that children with dyslexia demonstrated impairments in auditory processing which encompassed: encoding frequency loudness at the subcortical level, temporal integration in the primary auditory cortex, and complex pattern recognition in the secondary auditory cortex. In comparison, the children with ADD did not demonstrate any auditory impairments, and the children with ADHD demonstrated fewer auditory impairments compared to the group with dyslexia.

Challenging Aspects of Music Learning

The final group of research concerns challenges with music learning experienced by individuals with dyslexia. Existing studies published in peer-reviewed journals are both quantitative (Atterbury, 1983; Flach, Timmermans, & Korpershoek, 2014; Hébert et al., 2008; Jaarsma, Rukissenaars, & Van den Broeck, 1998) and qualitative (Ganschow, Llyod-Jones, & Miles, 1994; Geiger, 2015; Nelson & Hourigan, 2016). Quantitative research surrounds rhythm reading in children, note identification in children, and sight-reading in a university vocalist. Qualitative research explores themes pertaining to adult musicians' reflections on their musical experiences, and difficulties observed while teaching young music students with dyslexia. As the peer-reviewed literature surrounding this group contains few sources, it is the objective of the first article, presented in Chapter 2, to organize all the information available on this topic from a broader range of sources including dissertations and theses, pedagogical books, and informal reports. Presenting the existing articles with respect to their unique methodologies in this section will show why it is crucial to approach dysmusia research from a variety of perspectives.

Atterbury's (1983) experimental study focused on comparing text readers who were having difficulties which put their reading levels as approximately a year below what was expected (not specified as dyslexia) to controls. In total, the study comprised 40 participants, and they were divided into two main groups based on age (7 years old and 8 years old, respectively). Within each age group, there was a subgroup of low achieving readers (n = 10) and controls (n = 10). The testing materials included the rhythm subtest of Gordon's *Primary Measures of Music Audiation* (PMMA) (Gordon, 2001), as well perception tests constructed by the author which included tapping to a rhythm, speaking along with rhythm (syllables such as ta and ti), and tapping and speaking rhythms combined. On the author constructed tests, across the three modes of presentation, the groups with reading difficulties had the most accuracy with the tapped and spoken. Overall, the groups with reading difficulties performed less accuracy than their control groups. Regarding the PMMA, while the control groups had higher test means, their differences did not achieve statistical significance.

Flach, Timmermans, and Korpershoek (2014) considered the relationship between music staff design and mistakes made by children with and without dyslexia. Children between ages 8 and 13 were divided into three groups: dyslexia (n = 18), non-dyslexia (n = 41), and non-dyslexia but with reading difficulties (n = 13). The tool used in this study was a questionnaire that contained short pieces of written music in several conditions where one of the following features were varied: note size (four conditions), colour of the lines (four conditions), and direction of the stems (two conditions). Participants identified the note names on each musical excerpt. Types of mistakes included not identifying all the notes and identifying notes incorrectly. The results showed that note size had the most profound effect on performance accuracy among the participants with dyslexia. While the participants with dyslexia made approximately four times the numbers of errors when the note size was average, they only made approximately 1.5 times the number of errors when the note size was big. There was a moderate effect of stem direction, as the participants with dyslexia made more note identification errors compared to the other groups. There was no effect of colour on participants' performance.

Hébert and colleagues (2008) conducted a case control study, comparing test performance of one adult musician with dyslexia to a control group of adult musicians without dyslexia (n = 19). The test instrument included the following types of tasks: music tasks with visual input (pitch reading, rhythm reading, symbol identification, symbol discrimination, and visual recognition of familiar tunes), music tasks with auditory input (repetition of unfamiliar tunes, and auditory recognition of familiar tunes. All participants spoke aloud or sang their responses. In general, the case participant scored lower than the control group on all the music tasks. The biggest differences observed were on pitch and rhythm reading (sight-reading). The control group had a more accurate performance on reading compared to repeating. In contrast, the case was more accurate in repeating compared to reading. This pattern was the same for both the visual and auditory formats.

Jaarsma, Rujissenaars, and Van den Broeck (2008) designed a music reading intervention study to compare how children with and without dyslexia progressed in their ability to read music (on the score). Five children with dyslexia and four children without dyslexia were chronologically age matched. Over a period of five weeks, participants had a learning session once per week with a duration of 45 minutes each. The training included time for instruction and practice. At the end of each session, the experimenter discussed with the participants the mistakes that they made. The musical material learned comprised five series of notes in broken presentation (three tetrachords and two major scales). Each week, the participants were given a new series of notes to learn, though they spent some time reviewing previous series. Participants' knowledge of notes was tested through drawing, naming, and matching the notes to a card with the same picture. After the five-week intervention, the participants with dyslexia differed the most from the control group in their accuracy in matching notes to a card. On this task, the participants with dyslexia made mistakes on 26% of the trials compared to the control group, which made no mistakes.

Among the qualitative studies in the literature, two involved adult musicians and one focused on a child. Ganschow, Lloyd-Jones, and Miles (1994) interviewed six adult musicians about their musical strengths and weaknesses, as well as compensatory strategies. It is unclear if the interviews were structured, semi-structured, or unstructured. Each case was considered individually, and the salient concluding message of the authors is that the approach to learning music for individuals with dyslexia should be multisensory. In the case study by Nelson and Hourigan (2016), they interviewed five musicians with a semi-structured interview guide based on musical abilities and strategies for learning music. Their analysis approach was cross-case, as themes developed among all participants. Across their participants, salient themes included support for multi-sensory music teaching, isolating musical components, learning jazz and popular music, using technology in the music lesson, and favouring small group ensembles compared to large group classes. In contrast, the case study by Geiger (2015) was observational, as the researcher noted characteristics of a child as she learned how to read music on the recorder. The author observed that the child with dyslexia succeeded at learning how to read traditional musical notation over time and recommended that the selection of music teaching approach should be considered with the child's strengths and weaknesses in mind, instead of assuming that non-reading approaches will be best-suited to all children with dyslexia. While the specifics of the musicians' difficulties are described in more detail in article 1, it is clear that qualitative case studies to date have a focus on approaches to learning.

Purposes and Organization of the Dissertation

The remainder of the dissertation will explore four main research purposes and will be organized as follows: Chapter 2 is presented in article format and identifies the manifestations and indicators of dysmusia in the broader musical population. Chapter 2 also discusses how the manifestations and indicators are being reported among musical instrument group types (i.e., pianists, string players) as well as who is doing the reporting (i.e., musician, music teacher). Chapter 3 is presented in article format and uses laboratory developed music reading and writing tests, as well as a standardized audiation test, to create a performance baseline and explore test relationships in a population of children without dysmusia. Chapter 3 includes revisions to test selection made following pilot testing with a small population of musicians. Chapter 4 is presented in article format and explores relationships between music reading and music writing, and between music reading and audiation test performance in a group of young piano students without suspicion of dysmusia or diagnoses of dyslexia (n = 24). Chapter 4 considers the null hypothesis (no difference between test performance between music reading and writing paired conditions, and between sight-reading proficiency and audiation test performance). Chapter 5 is presented in article format and explores the case of a 10-year-old piano student with dyslexia. Chapter 5 considers both the qualitative themes generated from interviews with the student and her parent, as well quantitative data comparing her music test performance to age-matched and level-matched peers from Chapter 4 in addition to normalized data for processing speed and motor skills. Finally, Chapter 6 provides a general discussion of the dissertation’s main findings, as well as includes strengths and limitations, implications, and directions for future research.

Chapter 2: Manifestations and Indicators of Dysmusia: A Systematic Review of Qualitative Evidence[2]

Abstract

Many musicians struggle with music reading, never attaining fluency. Music reading difficulties could be explained by a phenomenon called dysmusia, which has a body of literature based on musicians with a dyslexia diagnosis and some literature suggesting dysmusia could be its own entity. Given the ambiguity about what dysmusia looks like and what deficits it might share with dyslexia, we sought first to identify manifestations and indicators of dysmusia among musicians considering reporting patterns among musicians, music teachers, and musical instrument types, and second, to sort which indicators are observable within a music lesson, and which point to possible shared deficits with dyslexia. We followed a systematic review of qualitative evidence to develop a corpus of literature on dysmusia. Our thematic analysis was guided by the British Dyslexia Association's list of manifestations and indicators of dyslexia. Results showed that manifestations include difficulties with written work, reading, sequencing, as well as motor and lateralisation skills, each with several indicators. Musicians referenced indicators more frequently than teachers. Pianists were the largest musical instrument group type. Reported indicators for dysmusia likely arise from cognitive deficits that are tested for dyslexia—slow processing speed, poor working memory, and auditory skills related to perception and discrimination—along with co-occurring deficits.

Keywords: dysmusia; dyslexia; music reading; music learning; pedagogy; piano

[2] Submitted to *Research and Issues in Music Education*

Background

Music reading is a complex transcription task requiring the simultaneous processing of cognitive, perceptual, and motor tasks (Jenson, 2016; Lee, 2004; Salis, 1977; Waters et al., 1998). It is an essential yet difficult skill, one with which many students and professionals struggle (Gromko, 2004; Gudmundsdottir, 2010; Sloboda, 1974). Unsuccessful attainment of music reading proficiency leads to frustration and often results in lesson abandonment (Gordon, 2000). In the pedagogical community, it is said that students vary in their progress towards fluent reading, and music teaching based on conventional reading primers does not suit all students (Gudmundsdottir, 2010; Mills & McPherson, 2006). Many testimonials about music reading difficulties exist in classical and popular music domains. For example, Backhouse (2001a) interviewed a classical pianist who, despite her musical career, experienced stress while learning and memorising new repertoire because of music reading difficulties. Nelson (2014) interviewed a composer who preferred composition over performance because it did not require proficiency in music reading.

History of "Musical Dyslexia"

Early writings about music reading difficulties are from the perspective of musicians with a dyslexia diagnosis learning music and pursuing professional careers (Ganschow et al., 1994; Miles & Westcombe, 2001; Miles, Westcombe, & Ditchfield, 2008; Oglethorpe, 2002). Prominent authors including Tim Miles, John Westcombe, Diana Ditchfield, and Sheila Oglethorpe, belonged to the British Dyslexia Association (BDA) and had experiences as amateur or professional musicians. Particularly, Tim Miles' research on dyslexia influenced the teaching materials in this group (Miles, 1986; 2006). To this group, a dyslexia diagnosis could lead to "differences" in learning music (a term chosen by the authors instead of "disorder" or "deficit" thereby promoting positive music learning experiences), thus music reading problems could be an extension of dyslexia and described with similar terminology (Miles, Westcombe, & Ditchfield, 2008, p. xiii). Miles (2001) referred to “manifestations” as clusters of related difficulties that, when taken together, form a meaningful whole of what having dyslexia could look like. Miles did not differentiate between manifestations that are more easily observable within a teaching context such as reading and writing, and those that would require specific testing (e.g., memory), because to obtain a diagnosis of dyslexia, an individual will have to be tested for all these manifestations. Indicators are signs of difficulties that can be categorised underneath manifestations, such as slow reading progress (British Dyslexia Association). Pedagogical books by authors within the BDA described several cases of musicians with dyslexia struggling with music reading at the beginner, amateur, and professional levels as well as cases from the music teachers’ perspective (Miles & Westcombe, 2001; Miles, Westcombe, & Ditchfield, 2008; Oglethorpe, 2002). Three books are well-known in the field. The first book, *Music and Dyslexia: Opening New Doors* (Miles & Westcombe, 2001) contains four chapters on individuals with dyslexia who are learning music and four chapters on musicians’ testimonies. The second book, *Music and Dyslexia: A Positive Approach* (Miles, Westcombe, & Ditchfield, 2008), contains nine chapters on individuals with dyslexia who are learning music and three chapters on musicians’ testimonies. The third book, *Instrumental Music for Dyslexics* (Oglethorpe, 2002) is a collection of insights for music teachers. There are also multiple informal reports in music teacher journals (Johnson, 2016; McCord & Fitzgerald, 2006; Proctor, 2000; Sitser, 1998) and magazines (Morrow, 2017; Wade, 2006). According to Rolka and Silverman’s (2015) systematic review of 23 studies on music and dyslexia, challenges that individuals with dyslexia may face while learning music, was the smallest category, comprising only three studies (Hébert et al., 2008; Ganschow et al., 1994; Jaarsma, Rujissenaars, & Van den Broeck, 1998).

Cuddy and Hébert (2006) proposed a separate disorder for music, called "developmental musical dyslexia", defining it as a "difficulty with learning to read music despite normal intelligence and opportunities [which] should be identifiable and should exist as an entity separate from text dyslexia[3]" (p. 203). The authors suggested that musical dyslexia should have its own identification criteria based on a framework that incorporates musical aspects including pitch and rhythm. Their proposition was based on a review of studies on musicians following a stroke; they noticed that some musicians' impairments were domain-specific and hypothesised the domain specificity could be part of the process of learning to read music versus text. In particular, they cited a case by Cappelletti and colleagues (2000) where the musician had an inability to read any musical notes even as text reading competencies returned. Moreover, the authors cited several cases of musicians whose text reading difficulties continued while music reading was spared following a stroke (Di Pietro et al., 2004; Signoret, et al.,1987; Tzortzis et al., 2000). Cuddy and Hébert argued that "deficits in music reading should be viewed within a framework that allows any component to be disturbed, with the possibility that the immaturity or lack of development of any of these components is a potential locus of deficit. Thus, a further hypothesis is that difficulties with learning to read music may be related either to pitch, rhythm, or symbol reading, or any combination thereof" (p. 203).

[3] Their definition is based on the standard definition of text dyslexia: a difficulty with learning to read despite normal intelligence and opportunities (Vellutino et al., 2004).

Organising Characteristics of Musical Dyslexia

Given that musical dyslexia is often discussed in the context of musicians with a dyslexia diagnosis, the characteristics of musical dyslexia have been discussed in a similar way. While the BDA uses terminology from dyslexia—manifestations and indicators—to discuss clusters of difficulties and specific difficulties that could largely be observable in a musical context, they have not taken the step to organise them in such a way that one could see at a glance which are being reported more frequently, which have been empirically measured in studies compared to those simply described, which are being observed by teachers compared to experienced by musicians, and which could be particularly relevant to certain instrument groups. Another possible approach to organising characteristics of musical dyslexia is by underlying deficits, that is, impairments requiring measurement (e.g., auditory, memory). Oglethorpe (2002) organised characteristics of musical dyslexia by what she considered to be primary deficits (occurring in most cases) and secondary deficits (occurring in some cases). These deficits were borrowed from dyslexia (see table 1).

Table 1

Oglethorpe's Organisation of Deficits Pertaining to Dyslexia in Music Learning

Primary	**Secondary**
Auditory (language based) - Slowness in processing what is heard (e.g., rhythm) - Difficulty in recognising rhyme - Difficulty in recognising sound segmentation and blending Visual - An inability to maintain a fixed focus (poor binocular control) - An inability to maintain steady directional progress - Susceptibility to glare - Lack of competence in recognition of similarities and differences in the text - The adjustment of focus from far to near, or vice versa, can cause extra strain Spatial - Confusion between left and right - A lack of competence in judging distance - The concept of up/down or high/low can be puzzling Memory - Both visual and auditory memory can be deficient in the short term - The kinaesthetic memory may take relatively longer to establish than the other two memories Disorganisation	Poor concentration Poor copying skills Anxiety Low self-esteem Frustration Family problems Erratic behaviour

Source: Oglethorpe (2002), "Chapter 1 – *Recognizing Dyslexia – The Way Forward"* (pp. 4-8)

While Oglethorpe's organisation of possible deficits in musical dyslexia are valuable in providing music teachers a resource and possible explanation for their students' challenges, there are some limitations. First, these deficits are borrowed from dyslexia without any clear testimonies that musicians have the same impairments. Second, the organisation provides inconsistent examples of each deficit; some are easily observable (e.g., confusion between left and right) while others are generalised (e.g., the kinaesthetic memory may take relatively longer to establish than the other two memories). Moreover, it is unclear to what extent these observable and generalised examples should be expected in music reading compared to other musical activities (e.g., is confusion with left and right happening when the student is reading music, when the student is not reading music, or both?).

It is likely that Oglethorpe's deficit organisation is borrowed from how other learning disorders related to dyslexia are discussed in literature. Understanding how other related learning disorders are compared to dyslexia regarding their deficits can shape how musical dyslexia is approached in research as either an extension of dyslexia or its own entity. According to the American Psychiatric Association (Pensetti, 2018) the current consensus is that dyslexia, dysgraphia, and dyscalculia belong to a family of related learning disorders. In cases of dyscalculia, children may demonstrate poor numerical processing but average or superior phonological processing and non-numerical verbal memory unlike in dyslexia (Landerl et al., 2004).[4] In dysgraphia, the issue for the individual is concerning letter writing and spelling which may interfere with written expression, rather than at the level of word reading as in dyslexia (Berninger & Richards, 2010).[5] Despite the presence of domain specific difficulties, dyslexia and dyscalculia share deficits such as lexical access and verbal working memory (Wilson et al.,

[4] "Developmental Dyscalculia (DD) is a specific learning disorder that is characterized by impairments in learning basic arithmetic facts, processing numerical magnitude, and performing accurate and fluent calculations (American Psychiatric Association, 2013).

[5] "The Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5) includes dysgraphia under the specific learning category, but does not define it as a separate disorder. According to the criteria, a set of symptoms should be persistent for a period of at least 6 months in the context of appropriate interventions in place" (Chung, Patel, & Nizami, 2020, p. 47).

2015). Dyslexia and dysgraphia share possible deficits in phonological processing, auditory processing, attention processing, visual-phonological processing, visual-magnocellular processing, and automatising information (Döhla & Heim, 2016).

Considering that most literature on music reading difficulties is presented with respect to dyslexia, we take the position that building our understanding of musical dyslexia comes from people reporting on music dyslexia in the field of dyslexia. The first step is to identify and organise manifestations and indicators of musical dyslexia such that we can constitute specific, observable examples of music reading difficulties as well as specific examples of difficulties pointing to possible underlying deficits shared with dyslexia. To minimise confusion when referencing both musical dyslexia and dyslexia, we should consider using more specific terminology. Gordon (2000) proposed that “developmental dysmusia” could be used instead of “developmental musical dyslexia” to refer to “an inability to read a musical score (p. 214). Gordon took the same position as Cuddy and Hébert (2006) that there might be a domain specific form of dyslexia for music disorder, because “in contrast to reading words, relevant information contained in musical notations is derived not through feature analysis of the notes but through analysis of their spatial location” (p. 214). More recently, Morrow (2017), a language therapist and cellist, used dysmusia, the same terminology as Gordon, to describe music reding difficulties. Both authors discuss cases of music students without known diagnoses of dyslexia who experience obstacles in learning to read music. Henceforth, we will use the term “dysmusia” rather than “musical dyslexia.”

Purpose

Dysmusia, the term used to describe incongruous music reading difficulties, is usually discussed in literature with respect to musicians with a dyslexia diagnosis but organisation of manifestations and indicators is unclear. Pedagogical books, scholarly papers, and informal reports discuss cases of musicians and their difficulties, but this information has not yet been categorised in the form of specific, indicators that are observable or suggestive of possible deficits. In the literature about dyslexia, the BDA provides clear descriptions of manifestations and observable indicators of dyslexia (e.g., reversing notes) as well as some references to possible underlying deficits (e.g., slow processing speed). Such a clear categorisation and description of manifestations and indicators (for dyslexia) as well as possible underlying deficits is not available for dysmusia. Establishing such a list would contribute to our understanding of dysmusia and would be beneficial for musicians and music teachers. Presently, it is difficult for music teachers to identify both the specific difficulties with which their students are struggling, as well as their causes. The distinction between observable difficulties and those that point to underlying deficits requires two levels of exploration. The unavailability of a list of difficulties causes confusion among those who might think they have a music reading problem but cannot easily compare their experience to others (Vance, 2004). Further, we do not know if musicians experiencing music reading difficulties and music teachers observing difficulties among their students, have a similar understanding about music reading and associated difficulties, which could tell us whether teachers are aware of these difficulties. Given the state of the literature, our study sought to answer the following questions:

1. What are the manifestations and indicators contributing to dysmusia?
    a. According to the type of literature (pedagogical and scientific)?
    b. According to the experiences of musicians and observations of music teachers?
    c. According to the musical instrument types?

2. What are the observable indicators of dysmusia, and which indicators are suggestive of underlying deficits shared with dyslexia?

To answer research question 1, we will organise specific music difficulties (indicators) into related clusters difficulties (manifestations) based on accounts of musicians experiencing music reading challenges and create a concise list of manifestations and indicators that considers the following:

a. There may be variance in reporting among scientific and pedagogical literature, given that scientific literature follows rigorous protocols and reporting standards, whereas the extent to which details are included is not standardised in pedagogical literature.
b. There may be differences between observation from musicians compared to music teachers, given that musicians are reporting on their lived experiences and music teachers can only report on what they observe.
c. There may be differences in reporting among musical instrument groups, given the differing requirements to decode and play instruments.

To answer research question 2, we will group indicators into being observable within a lesson and/or being suggestive of a potential deficit shared with dyslexia. We expect to find indicators suggestive of possible underlying deficits that could contribute to dysmusia, given that much pedagogical literature on dysmusia is written by authors in the dyslexia field who consider it related to dyslexia by shared deficits. Moreover, we expect to see a relationship regarding possible underlying deficits between manifestations and indicators of dysmusia and dyslexia, because we have seen shared deficits among dyslexia and dyscalculia as well as dyslexia and dysgraphia.

Method

Design

We conducted a systematic review of qualitative evidence, which follows a structured search process similar to a typical systematic review but looks for themes across qualitative studies to broaden understanding of a phenomenon rather than assessing studies for outcomes (Booth, 2006). This design considers evidence from individuals experiencing a phenomenon, which, in the health sciences, refers to the patient or practitioner (Booth, 2006; Reuvers, Bourbonnais, & Vanderspank, 2018). In our study, this refers to musicians and music teachers experiencing or observing music reading difficulties.

STARLITE Literature Search

To answer both research questions, the first step was a systematic literature search. Our analytic interest was manifestations and indicators of dysmusia—music reading and associated difficulties (Braun, Clarke, & Weate, 2016). Our search took place between 2017 and 2020, with no date limits set with the databases. Booth's (2006) STARLITE mnemonic guided our sampling (see table 2).

Table 2

Elements of the STARLITE mnemonic

S: Sampling strategy - Could be comprehensive, selective, or purposive
T: Type of studies - Could be fully reported (describes actual study types) or partially reported (uses an umbrella term such as "qualitative studies")
A: Approaches - State if approaches other than electronic were used (e.g., hand-searching, citation snowballing)
R: Range of years - Could be fully reported (start and end dates with justification) or partially reported (start and ends dates determined by chosen databases)
L: Limits - Functional limits that do not alter the topic conceptually (e.g., language)
I: Inclusions and exclusions - Conceptual limitations that mediate the scope of the topic area (e.g., geographical location, setting, or a specific focus of study
T: Terms Used - Could be fully present (provide example of search strings) or partially present (reports terminology but without syntax used)
E: Electronic sources - Databases used reported

Source: Booth (2006, p. 424)

We first attempted a comprehensive search by identifying all relevant articles, theses, and pedagogical book chapters and papers on the topic of dysmusia and music dyslexia. Second, to ensure an exhaustive search of the literature, we included both fully reported studies (e.g., theses, peer-reviewed articles), as well as book chapters and music articles that were broadly qualitative. Third, we set parameters for the data we reviewed, being electronic subject searches in English or French, with no date range set to include as many sources as possible. Fourth, we set a conceptual limitation to exclude papers about using music training as a remedial tool for individuals with dyslexia. Finally, we selected specific keywords and used the same keyword strings in the following databases: ProQuest Dissertations & Theses, Educational Resources

Information Center (ERIC), Journal Storage (JSTOR), Répertoire International de Littérature Musical (RILM), PubMEd, PychINFO, and Google Scholar (see table 3). Additionally, we searched pedagogical music journals: *Canadian Music Teacher*, *Clavier Companion*, and *The Strad*, which were selected for their available digital issue archives.

Table 3

Sample of Search Terms and Results

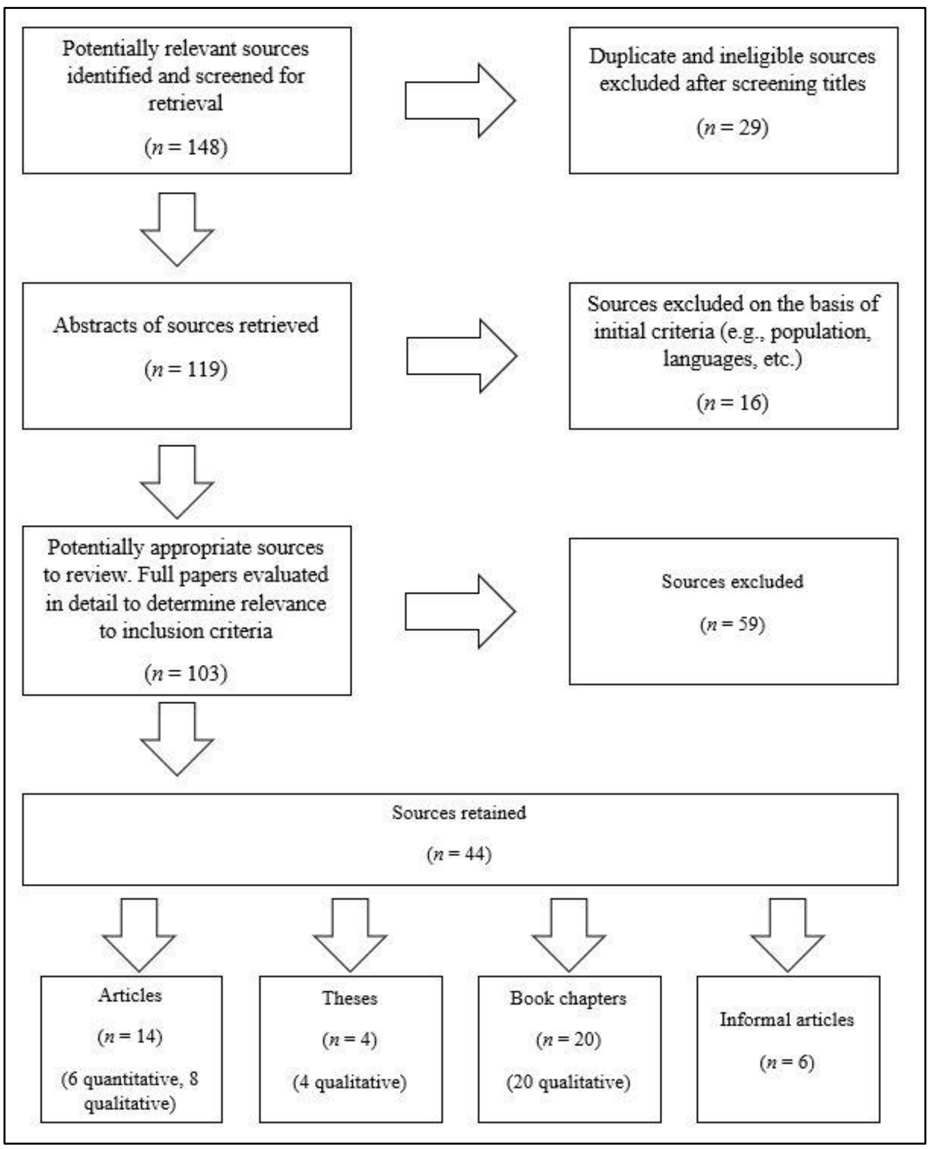
Article number	Keyword(s)	Citation
ProQuest		
01	Dyslexia (ab) + music (ab)	Nelson, K. P. (2014). *Successful strategies of individuals with dyslexia in the field of music: A comparative case study* (Order No. 3581077). Available from ProQuest Dissertations & Theses Global. (1545897798). Retrieved from https://search-proquest-com.proxy.bib.uottawa.ca/docview/1545897798?accountid=14701
02		Bishop-Liebler, P., Welch, G., Huss, M., Thomson, J. M., & Goswami, U. (2014). Auditory temporal processing skills in musicians with dyslexia. *Dyslexia, 20*(3), 261-79. doi:http://dx.doi.org.proxy.bib.uottawa.ca/10.1002/dys.1479
03		Nelson, K. P., & Hourigan, R. M. (2016). A comparative case study of learning strategies and recommendations of five professional musicians with dyslexia. *Update: Applications of Research in Music Education, 35*(1), 54-65. doi:http://dx.doi.org.proxy.bib.uottawa.ca/10.1177/8755123315581341
04		Witmer, N. S. (2015). *Music lessons from a tablet computer: The effect of incorporating a touchscreen device in teaching music staff notation to students with dyslexia* (Order No. 3686102). Available from ProQuest Dissertations & Theses Global. (1666860825). Retrieved from https://search-proquest-com.proxy.bib.uottawa.ca/docview/1666860825?accountid=14701
05		Forgeard, M., Schlaug, G., Norton, A., Rosam, C., Iyengar, U., & Winner, E. (2008). The Relation Between Music And Phonological Processing In Normal-Reading Children And Children With Dyslexia. *Music Perception, 25*(4), 383-390. Retrieved from https://search-proquest-com.proxy.bib.uottawa.ca/docview/222221043?accountid=14701

Characteristics of papers retained or excluded

The date range of retained papers was 1983 to 2017. Of 148 potentially relevant sources identified and screened for retrieval, 29 were excluded as duplicate and ineligible after their titles were screened. From the remaining 119 sources, 16 were excluded on the basis of initial criteria (e.g., population, languages, etc.), which left 103 potentially appropriate sources to review. Of these, 44 were retained as appropriate (see figure 1).

Figure 1

Characteristics of Papers Retained



Data analysis method

For research question one, we adopted the BDA's framework of manifestations and indicators of dyslexia (The British Dyslexia Association, n.d.) to inform our thematic analysis and we used the same framework for organising the manifestations and indicators of dysmusia (see table 4). We selected this framework because there is no existing framework for dysmusia and prominent authors investigating dysmusia belong to the BDA, using the same terminology of "manifestations" and "indicators." For music-specific items, we modified references to letters and language for references to notes and music where applicable, and deleted items that were not relevant to music. Then, for research question two, we grouped the manifestations and indicators into two groups—observable indicators within a lesson, and indicators that could be suggestive of a deficit. While the BDA's framework is useful for listing manifestations and observable indicators, it assumes that parents and children have access to psychological testing for indicators suggestive of deficits. The intent of our organisation is to provide musicians and music teachers a resource to know when to pursue further testing, so it is crucial to differentiate indicators easily observable within a lesson and those suggestive of deficits. When presenting this information, we considered similarities with dyslexia where applicable.

Table 4

Modifications to the BDA's framework

General indicators
Processing speed: slow spoken and/or written language / *the score*
Poor concentration
Difficulty following instructions
Forgetting words / *note names*
Poor auditory skills including audiation and discrimination
Written work
Poor standard of written work compared with oral / *music playing ability*
Produces messy work with many crossings out
Confused by letters / *notes, rhythms, intervals* that look similar
Poor handwriting with many 'reversals' and badly formed letters
Produces badly set-out written work, doesn't stay close to the margin
Uses unusual sequencing of letters or words / *notes*
Reading
Slow reading progress
Finds it difficult to blend letters together / *decode notes simultaneously*
No expression in reading / *in playing*, and poor comprehension
Hesitant and laboured reading, especially reading aloud / *sight-reading*
Omits, adds, repeats, or reverses words / *notes*
Fails to recognise familiar words / *notes*
Sequencing
Confused with place value, e.g., units, tens, hundreds/number values / *finger numbers*
Confused by symbols such + or - / *stems, expression markings (e.g., dynamics)*
Difficulty remembering anything in a sequential order, e.g., tables, days of the week, the alphabet / *repertoire, technical patterns*
Skills
Poor motor skills, leading to weaknesses in speed, control, and accuracy of the pencil/the fingers, the body / *poor eye-hand coordination*
Confused by the difference between left and right, up and down
Indeterminate hand preference
Performs unevenly from day to day

Note: Modified items are italicised.

We followed a flexible thematic analysis to answer our research questions (Braun, Clarke, & Weate, 2016). We chose a broadly critical realist approach which means our coding was informed by the BDA's framework, but we used our judgement to add codes specific to music. We used the BDA's framework, which provided a system of organisation by which we could create a list of manifestations and indicators of dysmusia (research question one). Our coding was broadly inductive; we looked for semantic ideas, meaning explicit difficulties. After coding our data according to the framework in research question one, we ensured that we accounted for type of literature, musical instrument type, music teacher or musician perspective for research question one, as well as if statements included reference to a known deficit (e.g., slow reading attributed to poor processing speed), for research question two. Following that, we sorted our manifestations and indicators based on if they would be easily observable within a lesson and/or suggestive of deficit of dysmusia, for research question two. Typically, the indicator would be expressed with a deficit (e.g., a musician reporting difficulty forgetting note names and attributing this to poor short-term memory).

Procedure

Our coding was conducted using NVivo Qualitative Analysis Software. Following protocols for thematic analysis, we read the corpus focusing on our areas of analytic interest: finding the manifestations (clusters of related difficulties) and indicators (specific difficulties) of dysmusia. Table 5 shows our levels of analysis.

Table 5

Levels of Analysis

Level 1: Manifestations (e.g., music reading)
Level 2: Indicators (e.g., difficulty sight-reading at an even tempo)
Level 3: Report type (e.g., musicians' self-reports (SR), music teachers' observations (TO), scholarly findings (SF); Musical instruments, if known (e.g., piano); Explicit references to known deficits (e.g., slow processing speed)

This following analysis is an example from our coding in which a pianist reported difficulty sight-reading at an even tempo. During the coding process, we looked for indicators (level 2), labelled them by report type (level 3), and added musical instrument if known (level 4). Thus for our pianist above, this analysis looked like, "SR – piano – difficulty sight-reading at an even tempo." Given that sight-reading is a component of music reading, that was the manifestation (level 1) under which we sorted it. There were several music-specific indicators that did not appear on the BDA's framework. For example, when musicians referred to difficulties with writing notes upon hearing them (in context of dictation), we created a new indicator, "difficulty with dictation" which was then categorised as a "writing" manifestation.

Results

Research Question 1

The first aim of our study was to determine the manifestations and indicators of dysmusia considering report type and additional information about musical instrument groups. Among the sources in the corpus, there were 59 musician accounts, 37 of which were descriptive (e.g., case studies), and 22 of which were reported in a chapter or article about music teaching or learning (e.g., a teacher's observation). Nearly half of the musicians (n = 29) were pianists. Of the pianists, there were 15 adults and 14 children. The next largest groups were singers (n = 11), all of whom were adults, and brass (n = 11), woodwinds (n = 10), strings (n = 7), and guitar and bass (n = 6). Many musicians were multi-instrumentalists (n = 22). In some instances, we could not discern instruments (n = 6). There were more adult musicians (n = 35) compared to children and adolescents (n = 25). There were 37 musician self-reports and 20 music teacher observations. Additionally, there were five studies documenting empirical findings, four with populations of children and one with a singular adult. Regarding gender, there were 20 females, of which 15 were self-reports and 5 were teacher observations, as well as 29 males, of which 21 were self-reports and 9 were teacher observations. Table 6 summarises the characteristics and manifestation presence of each musician or group of musicians we found that met our analytic area of interest, difficulty with music reading. All musicians listed below presented indicators of dysmusia in their music study or career as well as having a diagnosis of dyslexia.

Table 6

Characteristics of Each Musician or Musician Group

Articles	Report Type	Instruments	Reading	Writing	Sequencing	Skills
Quantitative						
40 children, 7-8 years old, 20 with dyslexia (Atterbury, 1983)	SF		Y			
72 children, 8-13 years old, 18 with dyslexia (Flach et al., 2014)	SF		Y			
IG, adult (Hébert et al., 2008)	SR & SF	Voice, piano, flute, guitar	Y			
9 children, 9 years-old, 5 with dyslexia (Jaarsma et al., 1998)	SF		Y			
Qualitative						
JL, adult (Ganschow et al., 1994)	SR	Voice, piano	Y			
RS, adult	SR	Voice, piano	Y		Y	
CL, adult	SR	Voice	Y		Y	
GT, adult	SR	Piano, voice, cello, saxophone	Y		Y	
ML, adult	SR	Viola	Y		Y	
PM, adult (Ganschow et al., 1994; Backhouse, 2001)	SR	Piano	Y		Y	
Noam, child (Geiger, 2015)	TO	Recorder	Y			
Paul, adult (MT, 1996)	SR	Trumpet	Y			
Jacob, child	SR	Trumpet	Y			
Undergraduate students, adults (Parsons, 2015)		Voice	Y			
Theses	**Report Type**	**Instruments**	**Reading**	**Writing**	**Sequencing**	**Skills**
DA, adult (Ashcroft, 2019)	SR	Piano	Y			
D, adolescent	SR	Guitar, bass guitar, tuba, trombone	Y			

O, adult	SR	Guitar, bass guitar	Y			
R, adolescent	SR	Guitar	Y			
Max, adult (Nelson. 2014)	SR	Piano, brass	Y	Y	Y	
Danny, adult	SR	Organ, piano, trumpet, percussion	Y		Y	
Randy, adult	SR	Brass	Y			
Stanley, adult	SR	Brass. piano	Y			
SS, adult (Solook, 2016)	SR	Percussion	Y	Y		
Cathryn, adult (Vladikovic, 2013)	TO	Piano	Y			Y
John, child	TO	Piano	Y			Y
Book chapters	**Report Type**	**Instruments**	**Reading**	**Writing**	**Sequencing**	**Skills**
41 children, 7-13 years old, 21 with dyslexia (Atkinson, 1993)	SF	Piano	Y			
PM, adult (Ganschow et al., 1994; Backhouse, 2001)	SR	Piano	Y		Y	
HP, adult (Poole, 2001)	SR	Piano, trombone, flute, saxophone, guitar	Y	Y	Y	
OS, adult (Smith. 2001)	SR	Recorder, voice	Y	Y		
Deidre, child (Ditchfield, 2001)	TO	Piano	Y		Y	Y
CO, adult (Oldfield, 2001)	SR	Flute	Y		Y	Y
ML, adult (Lea, 2001, 2008)	SR	Cello, guitar, voice	Y		Y	
SW, adult (Wood, 2001, 2008)	SR	Voice, harp	Y			
Philip, adult (Backhouse, 2001)	SR	Percussion, voice	Y		Y	
NC, adult (Clarke, 2001)	SR	Recorder, trumpet, cornet, piano	Y		Y	
JC, adult (Coker, 2001)	SR		Y			
AA, adult (Apostoli, 2008)	SR		Y	Y		
Fiona, adult (Bishop-Liebler, 2008)	SR	Voice, piano	Y	Y	Y	Y
Katie, adult	SR	Voice, saxophone, flute	Y	Y		
Lucy, adult	SR	Voice, piano	Y			
Ben, child (Oglethorpe, 2002)	TO	Piano	Y			
Anonymous, child	TO	Piano	Y			
Anonymous, adult	SR	Piano	Y			

Anonymous, child, learning “Queen of Sheba”	TO	Piano	Y			
11-year-old child	TO	Piano	Y			
Anonymous, child	TO	Violin	Y			
Trumpeter, adult	SR	Trumpet	Y			
8-year-old child	TO	Piano	Y			
Anonymous children)		Piano				
Student with poor binocular control, child	TO	Piano				
Informal articles	**Report Type**	**Instruments**	**Reading**	**Writing**	**Sequencing**	**Skills**
DD, adult (Wade, 2006)	SR	Organ	Y	Y		
MJ. adult (Crawford, 2015)	SR		Y			
Andrew, child (Proctor, 2000)	TO	Piano	Y			
Jessica, child (Knapp, 2007)	TO	Flute, piano	Y			
Various, children (Godfriaux-Maloy, 2014)		Piano	Y			
Various, children (Morrow, 2017)		Strings	Y			

Table 7 summarises the frequency of indicator reporting by each type of musical instrument group. Frequency refers to the number of musicians and teachers that reported a specific indicator.

Table 7

Frequency of indicators reported by musicians, music teachers, and supporting studies

Manifestations and Indicators	**Musicians' self-reports**	**Music Teachers' Observations**	**Supporting studies**
General indicators			
Processing speed: slow spoken and/or written language / *the score*	3		
Difficulty following lesson instructions	1		
Poor concentration	5	1	
Forgetting note names	8	4	2
Poor auditory skills including audiation and discrimination		1	
Manifestations			
Written work			
Poor standard of work compared with music playing ability	4	1	
Confused by notes-intervals-rhythms that look similar	1	1	
Produces messy work with many crossings out	3		
Makes mistakes specific to hearing and writing (dictation)	3		
Reading			
Slow reading progress	7	5	
Difficulty decoding notes simultaneously	9	1	
Hesitant and laboured reading, especially sight-reading	72	14	2
Omits, adds, repeats, or reverses symbols	4	5	
Fails to recognise familiar notes	1		

Confused by notes and intervals that look similar	2	2	
Confused by symbols such as dynamic markings, clefs, stems	2	2	1
Difficulty with transposition	1		
Reporting that the score appears differently	15		
Difficulty mapping notes on the instrument to notes on the staff	1	1	
Sequencing			
Confused with number values / *finger numbers*	1	4	
Difficulty remembering anything in a sequential order, e.g., sequences, repertoire, technical patterns	19	1	2
Skills			
Poor motor skills, eye-hand coordination	7	6	
Difficulty in lateralisation	3	2	

Notes: New indicators specific to dysmusia are italicised.

General indicators. We found five general indicators in the review process. According to the BDA, general indicators are overall signs that are not specific to word reading, writing, or numeracy, but could include identifying individual letters or numbers. It should be noted that all eight musicians that reported note identification difficulties experienced this while learning music on the staff (Backhouse, 2001; Ganschow et al., 1994; Oglethorpe, 2002, 2008; Poole, 2001; Smith, 2001; Wood, 2001). Furthermore, two music teachers inferred those difficulties with note identification result from poor tracking ability, as in the eyes not moving left to right (Howlett-Jones, 2001; Oglethorpe, 2001).

There are two supporting studies about children with a dyslexia diagnosis presenting dysmusia by forgetting musical note names. Flach and colleagues (2014) measured the note identification ability of children with dyslexia compared to controls. Children were given a questionnaire with musical excerpts varying in size, colour of the lines, and stem direction. Children identified note names, indicated whether the sequence was ascending or descending in pitch, and whether a note was on or between the lines. When the presentation of the music was normal size, children with dyslexia made four times the number of mistakes as the control group. However, when the music was enlarged, children with dyslexia made only 1.5 times the number of mistakes as the control group. Children with dyslexia made more mistakes than the control group when the direction of the music stems changed. Jaarsma and colleagues (1998) trained a group of children with dyslexia and a control group to read five series of notes on the treble clef. One challenging task for most children with dyslexia involved matching graphic representation on cue cards to a big chart. Of the 70 trials, children with dyslexia made 18 mistakes. About 30% were third transpositions, meaning a child indicated a note on an adjacent line or space.

Written work. Written work was discussed in the literature with respect to music theory assignments and composition at a university or professional level (Apostoli, 2008; Miles, 1996; Nelson, 2014; Solook, 2016; Wade, 2006). Messy writing contributed to composers being unable to read their own compositions (Apostoli, 2008; Poole, 2001; Solook, 2016). Mistakes in theory looked like swapping notes that are beside each other on the staff such as G and F (Ditchfield, 2008) and difficulty spotting consecutive fifths and octaves (Smith, 2001). We found an indicator that did not belong to the BDA's framework—difficulty with dictation—that required an addition by the authors. This was reported by three musicians who struggled to write notes on paper after hearing them played (Bishop-Liebler, 2008; Ganschow et al., 1994). Written work difficulties were reported more frequently by musicians (11) than by music teachers (2). Three singers reported written work difficulties, more than the other groups.

Reading. Most references with respect to music reading were that in general, the process was hesitant and laboured. There were 30 references to difficulties reading music without providing context, and reports were largely from musicians (25) compared to teacher observations (5). These reports did not specify whether the musician was engaging in one of the following three types of music reading: decoding a score for the first time, during the learning process, or after it had been learned. There were 21 references to difficulties in sight-reading without context, with 18 reports from musicians compared to one music teacher observation. Specific details included:

1. Pianists struggling with blocked intervals and chords
2. Difficulty reading music at speed or at a consistent tempo
3. Omitting, adding, repeating, or reversing symbols such as playing the last note of a phrase first or reversing measure numbers
4. Writing note names above the noteheads on the score
5. Mixing up notes on the lines and spaces

Five musicians inferred that their slow reading progress was due to a slow processing speed (Bishop-Liebler, 2008; Ganschow et al., 1994; Miles, 1996; Smith, 2001; Westcombe, 2001). A violinist inferred that getting lost in the score was due to visual confusion (Ganschow et al., 1994). Difficulties with music reading lead to stressful experiences performing in front of others (Ditchfield, 2001; Ganschow et al., 1994; Nelson, 2014; Parsons 2015).

We added four items to the BDA’s framework that are specific to music reading:

1. Confusing non-note symbols such as stem directions which altered pitches (the musicians erroneously thought stem direction could change the pitch of a given note)
2. Difficulty transposing notes from a score

3. Difficulty mapping the notes on the instrument to the notes on the staff
4. Inferences that the score appearing differently than fixed notes on a score results in slow reading and mistakes
    i. Symbols (e.g., ledger lines and notation) appear like meaningless dots
    ii. Symbols (e.g., ledger lines, lines and spaces, and notes) oscillate and move around
    iii. Being unable to discern to which line or space a note belongs

Reading difficulties were reported about four times more frequently by musicians (114) compared to music teachers (30). The following indicators were reported with similar frequency between musicians and teachers: difficulty decoding notes simultaneously; omitting, adding, repeating, or reversing symbols; confusing notes and intervals that look similar; confusing symbols such as dynamic markings, clefs, and stems; and difficulty mapping notes on the instrument to notes on the staff. A substantial difference in reporting was in hesitant and laboured reading, with about five times more reports from musicians compared to teachers. Regarding musical instrument groups, the following indicators were more frequently reported among pianists compared to others: difficulty decoding notes simultaneously; hesitant and laboured reading; missing out, adding, repeating, or reversing notes; and reporting that the score appears differently. Hesitant and laboured reading and reporting that the score appears differently were referenced by pianists about twice as frequently as the next-highest group, brass.

Sequencing. In context, sequencing difficulties looked like:

1. Confusion remembering chords in a sequence
2. Unable to sing back a sequence after hearing it, all the notes blend
3. Having to relearn the notes of a piece on a score with each practice

4. Difficulty with committing repertoire to long-term memory

We found two supporting studies: one about hearing and tapping back a rhythm, and another about memorising a technical sequence. Atterbury (1983) supported the thesis that tapping back a musical rhythm could be difficult for a group of children with dyslexia. She presented children with a rhythm pattern in three different conditions (tapped, melodic, and tapped and spoken). The group with dyslexia performed more poorly than the controls, but performed best when the presentation was tapped and spoken. This finding suggests that hearing and playing back difficulties are task-related, with condition of both the stimuli and the response possibly affecting performance. King (2008) conducted an informal study with 37 oboe students and discovered many of the individuals who screened probable for dyslexia also had difficulty playing descending scales. King inferred that, "[These students likely had] difficulties remembering the sounds and accessing the names of the names of the notes in reverse which had just been played going up" (p. 131).

Reports in the sequencing manifestation were more frequently made by musicians (19) compared to music teachers (5). Music teachers were concerned with finger numbers, while this was mentioned by one musician. Contrastingly, there were 19 musician references to difficulty remembering anything in a sequential order compared to one from a music teacher. Pianists reported difficulties with sequencing slightly more frequently than other musical instrument groups. All four references to difficulties with finger numbers observed by teachers concerned piano students. Difficulties in remembering anything in a sequential order were reported with similar frequency pianists, singers, brass players, and multi-instrumentalists.

Skills. Poor lateralisation was added to the framework as this occurs in a music context but not a text reading one. Three musicians reported difficulty discerning which hand is necessary to play notes on the staff (Ganschow et al., 1994), which we infer is a lateralisation problem. We found that poor eye-hand coordination was a common difficulty inferred by musicians as well as music teachers (Ditchfield, 2001; Ganschow et al., 1994; Smith, 2001; Vladikovic, 2013).

Skills difficulties were reported with similar frequencies between musicians (10) and music teachers (8). The most frequently reported indicator by both groups was poor motor skills, eye-hand coordination, with seven and six references, respectively. Among musical instrument groups, the most references were by pianists (13) with only a couple by singers and woodwinds. Again, most references by pianists were about poor eye-hand coordination.

In summary, we identified manifestations and indicators of dysmusia following the BDA framework. Differences in what was reported between musicians and music teachers suggest that teachers are not always aware of the difficulties musicians are experiencing. Just as manifestations of dyslexia form a picture of what it could present like, without all manifestations required for diagnosis, we found that musicians manifestations of dysmusia varied, too. We found only two cases of musicians with indicators belonging to all four manifestation groups, seven musicians with three, fourteen musicians with two, and the remaining musicians with only difficulties explicitly about music reading.

Research Question 2

In research question one, we identified manifestations and indicators of dysmusia with respect to how they were being reported, and now we present which indicators are observable within a lesson context, are suggestive of a possible shared deficit with dyslexia, or belong to both groups. Table 8 lists observable indicators and the indicators of possible deficits that would require testing to confirm.

Table 8

Observable and Possible Deficit Indicators

Observable Indicators	Possible Deficit Indicators
General Indicators	
- Forgetting note names - Poor auditory skills / e.g., audiating two excerpts as same or different, discriminating a pitch as higher or lower compared to another	*Cognitive* - Forgetting note names - Processing speed: slow spoken and/or written language / the score - Difficulty following lesson instructions - Poor concentration - Poor auditory skills / e.g., audiating two excerpts as same or different, discriminating a pitch as higher or lower compared to another
Manifestations	
Written work	
- Poor standard of work compared with music playing ability - Confused by notes-intervals-rhythms that look similar - Produces messy work with many crossings out - Makes mistakes specific to hearing and writing (dictation)	Auditory perception - Makes mistakes specific to hearing and writing (dictation)
Reading	
- Slow reading progress - Difficulty decoding notes simultaneously - Hesitant and laboured reading, especially sight-reading - Omits, adds, repeats, or reverses symbols - Fails to recognise familiar notes - Confused by notes and intervals that look similar - Confused by symbols such as dynamic markings, clefs, stems - Difficulty with transposition	*Cognitive* - Slow reading progress *Visual* - Reporting that the score appears differently

- Difficulty mapping notes on the instrument to notes on the staff	
Sequencing	
- Confused with number values / finger numbers - Difficulty remembering anything in a sequential order, e.g., sequences, repertoire, technical patterns	*Auditory or visuo-motor depending on context* - Difficulty remembering anything in a sequential order, e.g., sequences, repertoire, technical patterns
Skills	
	Motor - Poor motor skills, eye-hand coordination *Visuo-Spatial* - Difficulty in lateralisation

Under general indicators, we found these possible deficits common to dysmusia and dyslexia: slow processing speed, difficulty following lesson instructions, poor concentration, forgetting note names, and poor auditory discrimination. Some musicians inferred that slow processing speed contributed to note identification challenges (Bishop-Liebler, 2008; Westcombe, 2001). Regarding poor auditory skills, Oglethorpe (2002) described an experience teaching a child who had difficulties identifying high and low sounds:

> Given only two sounds to distinguish, he could identify the higher or lower sound, but faced with a short tune, he would be unable to imagine the shape of it, and his conception of high and low seemed to desert him. He could not hold the earlier sounds in his head in order to compare them with each other (p. 35).

Oglethorpe (2002) devoted a chapter to possible auditory challenges for musicians, cautioning that auditory challenges are not universally accepted for dyslexia diagnosis, and that moreover, poor audiation might be related to auditory memory challenges in musicians, which would require audiation testing. Only two general indicators are observable: forgetting note names, and difficulty discriminating between high and low sounds. However, the former may be related to a processing speed deficit, and the latter may be indicative of an auditory deficit.

All written work indicators are observable, however, mistakes specific to dictation could likely be related a potential shared deficit in auditory perception. A singer's biographer described that "she also reported difficulties in melodic dictation, where she was required to listen to a melody and write down the notes. She said that dealing with more than two notes was difficult for her to do at a normal speed, that she had to analyse each note in the chord and then figure out the chord" (Ganschow et al., 1994, p. 190).

Concerning reading, while most indicators are observable within a lesson, we found that slow reading process may be suggestive of a processing speed deficit (see general indicators) and that reporting that the score appears differently may be related to visual difficulties. The BDA lists the following visual difficulties that may co-occur with a dyslexia diagnosis: headaches and eyestrain associated with reading, text appearing blurred or going in and out of focus, text appearing double or alternating between single and double, difficulty keeping place in text, difficulty tracking across lines of text, discomfort with brightness of the page or contrast between text and background, and text that appears to shimmer or flicker. The BDA considers visual difficulties part of "co-occurring differences" meaning it might not be part of dyslexia, rather, another abnormality requiring an optometrist's examination. The musicians who reported odd score appearances used similar terminology. A pianist described:

> I couldn't tell whether stems went up or down, music did not look the way it sounded, and sharps and flats could hide near notes they were not supposed to have anything to do with […] ledger lines occasionally 'faded out' so that counting them was an unreliable way to figure out what the note was (Sitser, 2008, p. 44).

Therefore, the same underlying visual difficulties that could co-occur in individuals with dyslexia (meaning many individuals with dyslexia present visual difficulties but they are not required for dyslexia diagnosis) could also co-occur in musicians with dysmusia.

We found one study that supported the notion that notes moving around could affect music reading. Atkinson (1993) suggested that a subset of children with dyslexia have poor binocular coordination, a visual condition that could affect how notes on the score are perceived. In his study of 13 child musicians with dyslexia and poor binocular coordination, the experimental group performed more poorly in sight-reading tasks compared to peers matched on instrument and experience. Some children with dyslexia commented that notes were running into each other, jumping around on the staff, and appeared blurry.

Of the two indicators reported under sequencing, confusion with finger numbers is the most easily observable. Difficulty remembering anything in a sequential order is still observable but would require further testing to determine if it is linked to a memory deficit. In dyslexia diagnosis, letter-number sequencing is measured with the working memory index on the Wechsler Intelligence Scale for Children (WISC). Some musicians with difficulties in remembering sequential material referred to poor memory. A flutist referenced his poor working memory as part of his dyslexia and compensated with strategies for memorising complex melodies and rhythms (Walker, 2019). A pianist inferred her working memory was vulnerable to interference from an out-of-tune piano (Backhouse, 2001). Another musician inferred that his difficulties with memorisation on the double bass but not with the guitar were related to the interaction of kinaesthetic and aural memory:

> Aural memory linked to muscle memory is a powerful combination that clearly aided my memorising skills on the guitar. The fingers in both hands are in direct contact with the strings; so the neurological connections are direct. (Lea, 2008, p. 94).

These descriptions suggest that dyslexia and dysmusia share a memory deficit.

Considering skills, most references were to poor eye-hand coordination (13), which is part of motor skills. In addition to being on the BDA's framework for dyslexia, it is also considered a co-occurring difficulty (meaning that it is likely individuals with dyslexia will also experience poor eye-hand coordination). While eye-hand coordination was referred to by musicians, they did not report any indication of having been diagnosed with a motor deficit in addition to their dyslexia diagnosis. However, we found a book chapter by Oglethorpe (2002), which discussed the possible motor difficulties music students with dyslexia could experience as well as exercises to help students develop these skills.

In summary, we found indicators of dysmusia that are easily observable within a music lesson while other indicators that might suggest a deficit shared with dyslexia. Possible shared deficits may relate to processing speed, auditory skills, and memory, as well as possible co-occurring visual and motor difficulties as in cases of dyslexia.

Discussion

In research question one, we found interesting differences among musicians and teachers regarding frequency of indicators reported. Musicians referenced difficulties in music reading about four times as frequently compared to music teachers, particularly for "hesitant and laboured reading." One possible explanation is that while musicians might self-identify as hesitant readers, music teachers see strengths. In Frankel's (2017) reading study, a self-identified poor reader had strong prereading strategies and ability to comprehend text, according to his teacher. Furthermore, no teachers referenced reports of students indicating that the score appears differently to them.

An alternative explanation is that musicians might not disclose difficulties. One individual admitted to not telling music teachers about his dyslexia diagnosis (Nelson, 2014). Nearly all references to difficulties in remembering sequences were reported by musicians. A conceivable reason is that musicians' low self-rating might not translate to what others hear. A bassist described his natural memorisation abilities as very poor, yet prided himself on dedication to practice (Lea, 2008). In general, references made by music teachers were about obvious mistakes, suggesting that teachers might not be aware of students' struggles. Knapp (2007) assumed a student had vision problems after noticing music reading difficulties, but then the student revealed a dyslexia diagnosis. Most reports by musicians were made by professionals, while teachers reported about children in the process of learning. It is possible that most of these children discontinued lessons or abandoned music.

Among the various musical instrument groups, pianists made more than three times as many references to difficulties than other musicians. One possible explanation is the processing demands required to read piano music. Sergent (1993) writes that sight-reading music "is an extremely complex task that involves a considerable number of operations, and it is hard to think of any other human activity that calls for the implementation of so many processes for their immediate realization" (p. 169). In addition to operations such as processing pitch and timing, the execution of music reading requires a motor output with both hands (Gudmundsdottir, 2010). Furthermore, sight-reading piano music involves two staves, with multiple notes played simultaneously, covering a wide range on both the keyboard and the score.

We found that literature on dysmusia was largely pedagogical with few supporting studies. Particularly, it was surprising that the existing studies for music reading in the context of dyslexia were specific to note identification and did not include note music reading at an instrument (Flach et al., 2014; Jaaersma et al., 1998). This reveals a need to empirically measure how individuals with varying levels of music reading difficulty perform on tasks that include decoding in real time at their instruments. Comparatively, reading sight-words is an integral part of dyslexia assessment (Snowling, 2011). Moreover, no existing studies on music writing and dyslexia indicate that development is needed here to further our understanding of dysmusia.

Given that poor written work is a significant manifestation of dyslexia (Ellis, 2016; Sumner, Connolly, & Barnett, 2014) that has been measured with writing tests (Blampain, Gosse, & Reybroeck, 2021; Re & Cornoldi, 2015) these can inform how researchers can proceed here. The two studies found for sequencing in the context of music and dyslexia (Atterbury, 1983, King, 2008) are about specific contexts and not necessarily reflective of the entire picture of dysmusia. Atterbury's study is relevant to a motor response (clapping) following an auditory stimulus (beat) whereas King's study is relevant to both decoding at sight on the oboe and recalling scale finger patterns. Future studies on dysmusia would require specific sequencing tasks for both auditory-motor as well as visuo-motor activities. Including both auditory-motor and visual-motor sequencing tests is commonplace in dyslexia assessment (Nicolson & Fawcett, 2006). We found no supporting studies on eye-hand coordination and lateralisation with reference to music and dyslexia. In the field of dyslexia, an individual demonstrating poor eye-hand coordination may have deeper visual problems (Przekoracka-Krawczyk et al., 2017). This could be a potential avenue for exploration in dysmusia.

In research question two, we found that dysmusia and dyslexia may share common deficits with dyslexia—poor processing speed, auditory skills, and working memory—as well as visual and motor skill difficulties which often co-occur with dyslexia diagnosis according to the BDA. Peretz (2016) considered that neurodevelopmental disorders share a cognitive origin, as exemplified in the study by Weiss, Granot and Ahissa (2014), who studied musicians with and without dyslexia. Musicians with dyslexia scored poorly on auditory memory for rhythm, melody, and speech. This study raised the point that poor auditory working memory could interfere with music reading accuracy. The relationship between rhythmic and reading abilities has been shown to be consistent in primary school children over time (David et al., 2007), revealing a need to examine this relationship in children learning music, where rhythm is essential. While recent studies focused on music interventions to improve reading fluency (Forgeard et al., 2008; Goswami et al., 2013; Leong & Goswami, 2014; Long, 2014), the next step is exploring music reading difficulties in the early years of education.

Conclusion

Our study had two aims, first, to determine manifestations and indicators of dysmusia considering report type and musical instrument types if applicable, and second, to explore which indicators are observable within a music lesson, and which are indicative of a possible deficit shared with dyslexia. Following the BDA's framework, we were able to categorise manifestations and indicators into four groupings: general indicators, written work, reading, sequencing, and skills. Some music-specific items were added under written work, reading, sequencing, and skills, notably mistakes specific to hearing and writing, difficulty with transposition, and reporting that the score appears differently. There were several indicators for each grouping. Musicians referenced more types of indicators than music teachers, suggesting teachers may be unaware of several challenges faced by their students. Pianists reported difficulties more frequently than other musical instrument types, likely because more accounts from pianists exist. We consider some indicators as being both observable as well as a sign of a possible deficit shared with dyslexia: forgetting note names, poor auditory skills, slow reading progress, difficulty with hearing and writing notes (dictation), and difficulty remembering anything in a sequential order. Possible deficits include: processing speed, auditory skills, working memory, visual difficulties, and motor skills. We conclude that dysmusia and dyslexia share similar deficits that manifest in different domains.

Limitations

We acknowledge the following limitations on what the data can tell us. First, the corpus comprised a variety of sources, many of which appeared more anecdotal than scientific. We mitigated this by finding specific difficulties pertaining to dysmusia in the informal reports and using the scientific literature to support. Furthermore, the informal reports provided a better understanding of indicators unique to dysmusia. Second, we cannot know the extent to which authors were comprehensive or descriptive. We managed this by adding context provided (e.g., any descriptors relevant to the difficulties) and not making assumptions (e.g., referring to a musician's self-report of slow processing speed as an inference). Third, we realize that indicators of dysmusia and dyslexia appear in different contexts so the selection of the BDA's framework would not account for all music items. By adding several music-specific items, we exhausted the literature.

Implications for further research

This paper is the first step in understanding dysmusia. Researchers can use these manifestations and indicators to develop a screening tool for a specific population. Based on our findings, a tool for young piano students would be feasible. To this end, screening tool development would first involve a review of specific tests to account for each manifestation and indicator, followed by a preliminary data collection from a group of piano students to find patterns among music reading and test scores.

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Chapter 3: Towards Developing a Screening Tool for Dysmusia: Selection of Tests Following Critical Review

Abstract

Dysmusia, a phenomenon pertaining to incongruous difficulties in music reading, is understood by its manifestations (clusters of related difficulties) and indicators (specific difficulties), some of which point to shared deficits related to dyslexia. Testing for dysmusia using quantifiable measurements has been suggested by Cuddy and Hébert (2006) but no tests for dysmusia exist. However, we can follow examples of what has been done for amusia (a music perception disorder) in the music domain, and dyslexia in the language domain. Developing a dysmusia screening tool would provide researchers with a method to identify at risk and not at risk children with tests sensitive to their developmental ages. The current step in tool development is test review. We conducted a critical review of tests for manifestations and indicators of dysmusia following a systematic literature search. Twenty-three tests met inclusion criteria. Each test was appraised for ease of administration, sensitivity to children with learning disorders, reliability, validity, and recent normative data. Upon review, we selected seven tests accounting for nearly all manifestations and general indicators of dysmusia, apart from music writing. We situate the tests we selected among literature for music and dyslexia and discuss how we formed our writing tests to complete our proposed screening tool. Following a feasibility pilot study, we conclude that our proposed screening should undergo further development though administration to a group of children in the early years of music study.

Keywords: dysmusia, musical dyslexia, screening tool, test review

Background

Dysmusia, a phenomenon pertaining to incongruous difficulties in music reading, can also be a barrier in the acquisition of music reading skills (Cuddy & Hébert, 2006; Gordon, 2000). How dysmusia manifests has been discussed in literature as both an extension of dyslexia, with respect to musicians with a dyslexia diagnosis (Miles & Westcombe, 2001; Miles, Westcombe, & Ditchfield, 2008; Oglethorpe, 2002) as well its own domain-specific phenomenon in music (Cuddy & Hébert, 2006; Gordon, 2000). We take the position that dysmusia may be either an extension of dyslexia or its own domain-specific phenomenon with some shared deficits with dyslexia. To understand dysmusia through a quantitative lens, we could identify and measure its manifestations and indicators in a population of developing musicians, to explore if trends that appeared in the qualitative review also appear with empirical measurement (Authors, 2022a). In our previous work, we organised manifestations and indicators based on a qualitative analysis of the existing literature (see table 1). We identified manifestations to be difficulties with music reading, music writing, music sequencing, eye-hand coordination, and visual-spatial ability. Most reports pertained to children learning piano. Music teachers and musicians had different reporting patterns suggesting that not all manifestations and indicators of dysmusia experienced by musicians are observable by teachers. Furthermore, we discussed that not all indicators of dysmusia are easily observable, and several point to possible deficits that are shared with dyslexia: slow processing speed, poor auditory skills, visual abnormalities, poor working memory, and poor motor skills.

Table 1

Manifestations And Indicators of Dysmusia, Definitions and Examples

Manifestations / Indicators	Definition and examples
General indicators	
Slow processing speed	Taking a long time to decode all the symbols on a score such as notes, rhythms, expressions, compared to others
Difficulty following lesson instructions	Self-explanatory; may be related to a poor memory
Poor concentration	Having difficulty focusing during a practice or lesson, could lead to fatigue or headaches, or not staying on task (particular in children)
Forgetting note names	Difficulties associating a note name (e.g., letters) to a note on the staff or keyboard; might have no difficulties in decoding yet struggle with naming
Poor auditory skills including audiation and discrimination	Audiation: When presented with a musical excerpt or excerpts, difficulty ascribing meaning to them (example, remembering the melody or rhythm such that one indicates what was heard was familiar or unfamiliar, or same or different.[6] Discrimination: When presented with at least two pitches, having difficulty identifying which is higher or lower; also overlaps with difficulty with dictation and difficulty remembering anything in a sequential order - *Example: difficulty with ear-training exercises*
Manifestations	
Music reading	
Slow reading progress	Taking more time compared to peers to learn repertoire through reading it
Difficulty decoding notes simultaneously	When presented with an interval or chord, having to stop, determine each note, and starting again - *Example: "seeing" notes as a block, not recognizing the individual notes*

[6] The term "audiation" on the Gordon Institute for Music Learning website is described in the following way. "It is a cognitive process by which the brain gives meaning to musical sounds. Audiation is the musical equivalent of thinking in language. When we listen to someone speak we must retain in memory their vocal sounds long enough to give meaning to the words the sounds represent. Likewise, when listening to music we are at any given moment organizing in audiation sounds that were recently heard. We also predict, based on our familiarity with the tonal and rhythmic conventions of the music being heard, what will come next (https://giml.org/mlt/audiation/)

Hesitant and laboured reading, especially sight-reading	Difficulty with fluency in music reading, could be during rehearsed reading and/or during sight-reading; stop-and-start playing
Omits, adds, repeats, or reverses symbols	Self-explanatory
Fails to recognise familiar notes	Difficulties retaining information about notes such as name, place on the instrument, place on the staff
Confused by notes and intervals that look similar	Mistaking similar symbols - *Examples: switching notes that are adjacent to each other on the instrument or staff, switching notes that are on adjacent lines or spaces on the staff, confusing notes on the treble clef for the bass clef or reverse.*
Reporting that the score appears differently	Instances where a musician has their own experience of what the score looks like - *Examples: symbols oscillate, jump, fade in-and-out, are blurry, appear as double, appear as dots and squiggles*
Difficulty in mapping notes on the instrument to notes on the staff	Recognising notes when presented on the instrument but having difficulty finding the matching note on the staff
Music writing	
Poor standard of work compared with music playing ability	Assuming the musician has had instruction in music writing alongside music lessons, the musician demonstrates weaker abilities in writing compared to their playing level
Confused by notes and intervals that look similar	See music reading
Produces messy work with many crossings out	With pencil/pen and paper assignments, there will be many evident mistakes and retries
Makes mistakes specific to dictation (hearing and playing)	Difficulties writing the correct pitches based on hearing them played in the context of a dictation assignment
Sequencing	
Confused with finger numbers	Choosing not to follow the finger numbers on a page because reading the finger numbers slows down the reading of the musical notes; or, Difficulty remembering which finger numbers are associated with each finger
Difficulty remembering anything in a sequential order (e.g., sequences, repertoire, technical patterns)	During or between practice sessions, having difficulty retaining information about notes recently played, having to re-decode them as if it were the first time - *Examples: for sequences, having difficulty remembering the notes within a measure during a practice session; for repertoire; having difficulty memorising a piece; for technical patterns, forgetting the notes of a scale when playing the notes in a descending order*
Eye-hand coordination	

Poor motor skills, eye-hand coordination	Difficulty maintaining reading fluency while coordinating the eyes on the score with hands on the piano, often shifting gaze between the eyes and the hands
Visual-spatial ability	
Difficulty with lateralization	Difficulty knowing which hand is meant to play which notes

A Screening Tool for Dysmusia

We recognise that dysmusia is related to dyslexia, but it does not have its own screening tool as in dyslexia. Cuddy and Hébert (2006) suggested that a screening tool for dysmusia could quantifiably measure difficulties pertaining to aspects of music reading (e.g., pitch and rhythm). To clarify, when we use the term "screening tool" we refer to a tool that will provide an assessment, as this is what has been used for educational assessments of dyslexia (Chatterji, 2003). According to Chatterji (2003), a screening tool for assessment is "a systematic device for generating information on a construct" (p. 12). Developers of screening tools must specify the purpose of their instrument as one of the following: teaching and learning, program planning, screening and diagnosis of exceptionalities, guidance and counselling, admissions or certifications, and research and development. Our intent is to develop a screening tool that could screen children for an exceptionality in their music learning (dysmusia). Screening tools are typically administered to children who are in kindergarten or grade one, allowing time for intervention to mitigate more significant reading problems in the future (Catts et al., 2013). Our tool would be administered to children in the early stages of music learning, for the purpose identifying difficulties such that the music teacher can accommodate more customised learning in the future. According to Christo, Davis, and Brock (2009), successful screening tools for dyslexia can identify both children who are at risk and not at risk. There can be four outcomes in the screening tool: true positive (are at risk of dyslexia and are identified as at risk), false positive (are not at risk for dyslexia but are identified as being at risk), true negative (are not at risk for dyslexia and are not identified as at risk), and false negative (are at risk for dyslexia but are not identified as being at risk). Because there is no diagnosis for dysmusia presently, the first screening tool would only have two possible outcomes, at risk and not at risk, until future research confirms dysmusia as its own learning disorder.

Testing for Congenital Musical Exceptionalities

While tests for dysmusia with children are largely unexplored, we can gain insight from how testing development is approached with respect to congenital amusia, an established pitch discrimination disorder (Peretz et al., 2013).[7] Peretz and her colleagues explained that detection of amusia in childhood is important from a clinical point of view; detecting difficulties while the brain is very malleable offers a possibility of intervention. They adapted their testing battery for adults, the *Montreal Battery of Evaluation of Amusia* (MBEA) because of its foundation on theoretical principles, psychometric criteria, sensitivity, normally distributed scores, and good test-retest reliability. The result was a condensed version for children, the *Montreal Battery for Evaluation of Musical* Abilities (MBEMA). The MBEMA comprises five subtests: contour, interval, scale, rhythm, and memory. Following a study of Canadian and Chinese children, Peretz and her colleagues cautioned that the same statistical criterion for adult diagnosis of dysmusia (2 SD below the mean) is not sensitive enough for a younger population of children, especially those who are six to eight years old. Particularly, they noted a marked change in scores of children between six and seven years old and attributed it to developmental changes. Thus, we

[7] "Individuals with congenital amusia are unable to recognize well-known tunes in the absence of lyrics, and they have difficulty differentiating melodies on the basis of pitch cues alone, despite having normal hearing, speech, and intellectual ability, and ample opportunity for musical exposure (Peretz et al., 2013, p. 1).

recognise that screening children for dysmusia should consider specific developmental age ranges.

Research Problem

Dysmusia has several indicators, however, a concise list of tests with which we could test a population of piano students does not exist. Test selection is a necessary step in developing a screening tool (Chatterji, 2003). Understanding dysmusia is important because music reading difficulty is a problem faced by many musicians, especially children (Gudmundsdottir, 2010; Gromko, 2004; Mills & McPherson, 2006; Sloboda, 1974). We could investigate how young piano students with varying music reading abilities perform on tests for all manifestations and indicators. Within that specific population, we could observe any trends that appear when we compare their test results to standardised scores. The purposes of the study are to select empirical tests specific to the manifestations and indicators of dysmusia which will lead to hypotheses about which tests could comprise a novel screening tool and to conduct an initial feasibility study with the selected tests.

Method

Design

We conducted a critical review of existing tests for manifestations and indicators of dysmusia. According to Grant and Booth (2009), a critical review is an extensive search and evaluation of literature that contributes to concept development and is a necessary intermediate step leading to testing. There is flexibility for how the review is conducted, but it can follow a similar pattern to other reviews, beginning with defining key terms and a systematic literature search (Bradley-Johnson, 2001; Cullen, O'Neill, Evans, Coen, & Lawlor, 2007; Grant & Booth, 2009; Kay et al., 2011).

Defining terms

The first step was providing definitions of each indicator to inform our search strategy (see table 1 in the literature review).

Systematic literature search: STARLITE

Given that our search goal was to find tests to review, the second step was following a template to assist with sampling. Booth's (2006) STARLITE mnemonic was ideal because it accounted for both database searching and reference searching (see table 2).

Table 2

Elements of the STARLITE Mnemonic

S: Sampling strategy
- Could be comprehensive, selective, or purposive

T: Type of studies
- Could be fully reported (describes actual study types) or partially reported (uses an umbrella term such as "qualitative studies")

A: Approaches
- State if approaches other than electronic were used (e.g., hand-searching, citation snowballing)

R: Range of years
- Could be fully reported (start and end dates with justification) or partially reported (start and ends dates determined by chosen databases)

L: Limits
- Functional limits that do not alter the topic conceptually (e.g., language)

I: Inclusions and exclusions
- Conceptual limitations that mediate the scope of the topic area (e.g., geographical location, setting, or a specific focus of study

T: Terms Used
- Could be fully present (provide example of search strings) or partially present (reports terminology but without syntax used)

E: Electronic sources
- Databases used reported

(Booth, 2006, p. 424)

We decided our sampling strategy would be purposive. According to Booth (2006), this meant that we sought tests from specific disciplines: music, psychology, education, and motor control. Because we needed access to all testing materials, we selected fully reported tests that provided materials and protocols. To ensure we included as many tests for review as possible, we searched within article references. We did not set a range of years on our searches. Functionally, we set language limits to English because this is the language in which the screening tool will be developed. We excluded tests that were designed for adults only. Regarding terms used, we followed the manifestations of dysmusia to guide our search strings (see table 3).

Table 3

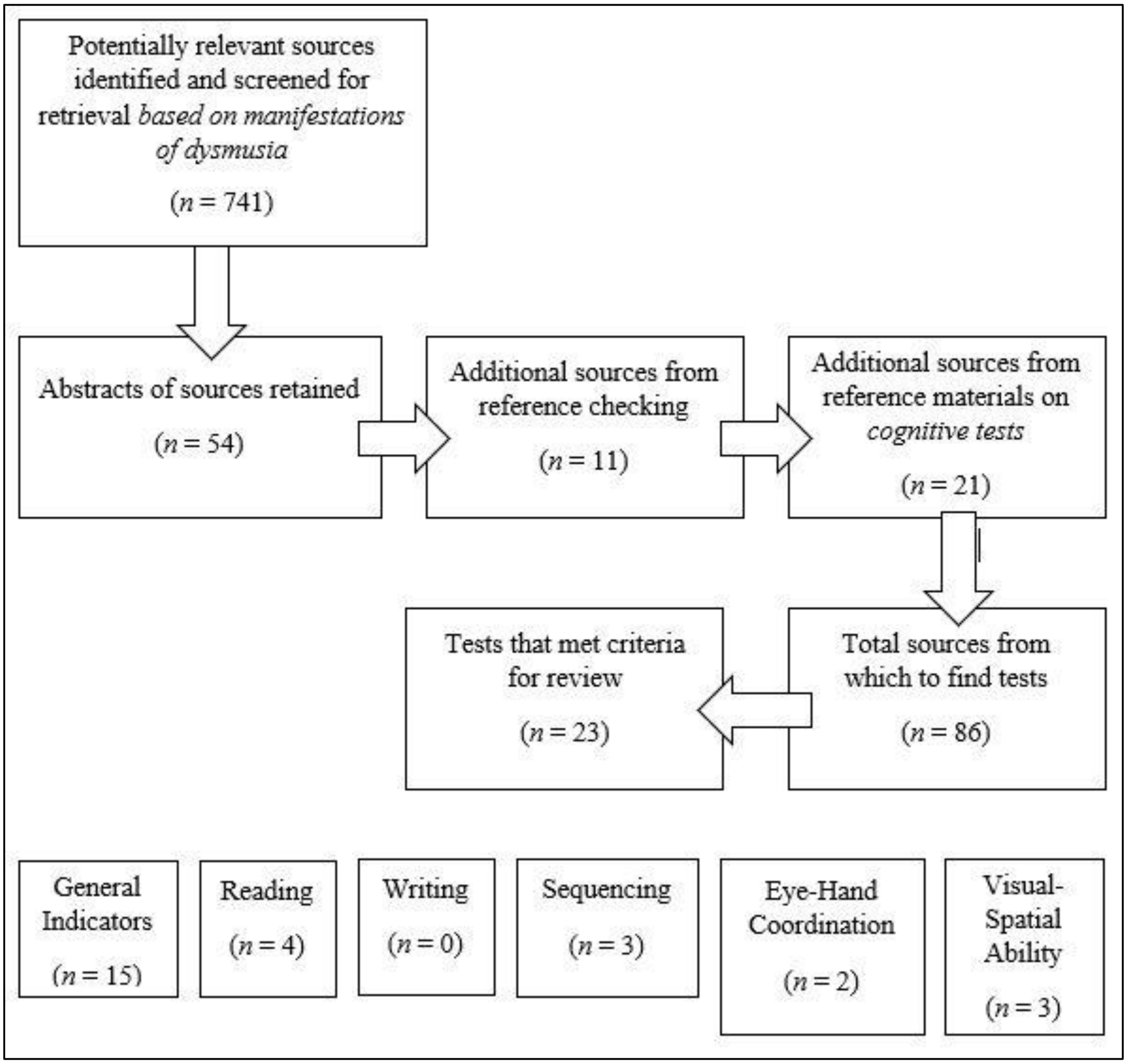
Sample of Search Strings

Keyword combination
Music reading (abstract) + children (abstract)
Music writing (abstract) + children (abstract)
Music sequencing (abstract) + children (abstract)
Music memory (abstract) + children (abstract)
Eye-hand coordination (abstract) + children (abstract) + music (abstract)
Visual-spatial (abstract) + children (abstract) + music (abstract)

Finally, our searchers were conducted in the following electronic databases: ProQuest Dissertations and Theses, Academic Search Complete, Cochrane Library, Ebook Central, Education Source, ERIC, Google Scholar, Journal Storage (JSTOR), Music Database, PsychINFO, and Répertoire International de Littérature Musical (RILM). Additional books were consulted in music (Colwell, 2006; Comeau, 2009; Froseth, 2003; Inabinet, 2005) and psychology (Goldstein & Naglieri, 2011; Mitrushina, 2005; Reise & Rodriguez, 2013) as well as an unpublished music reading test at our laboratory. Our search progress is outlined in figure 1.

Figure 1

Search Process



Through our database searches completed between 2017 and 2020, we found 741 potentially relevant sources based on keywords pertaining to the manifestations of dysmusia. After screening the sources based on titles, we retained 54 sources and their abstracts. Then, we reference checked our sources and found 11 additional items. Given that a dysmusia screening tool requires cognitive testing, we searched 21 reference materials on cognitive tests. In total, we found 86 sources from which we could determine tests for review.

Inclusion Criteria for Test Corpus

Three criteria were used for test inclusion based on our study purpose: 1) relevant to each manifestation of dysmusia based on information from the title, abstract, or short description; 2) quantitative design to provide empirical data, and 3) intended for children to suit our screening tool population. We found 23 tests that met our inclusion criteria. It is important to note that some tests appeared under more than one manifestation; these will be presented and described on their first appearance but only listed in subsequent sections.

Results and Analysis

After the search process, we identified 23 tests for critical review and selection (see table 4 for complete test information).

Table 4

Tests Identified for Critical Review and Selection

					Reliability coefficients		
Test name	**Abbreviation**	**Ages (years)**	**Admin time (min)**	**Source ref.**	**Inter-rater & intra rater**	**Internal consistency**	**Test-retest**
Clock Drawing Test for Children	CDT	6-12	4	Eden, Wood, & Stein, 2003; Koch, Hahn, & Szecsey, 2004; Cohen, Riccio, Edmonds, & Kibby, 2000	0.82 ($p < 0.05$) & 0.93 ($p < 0.05$)	PBU	PBU
Children's Color Trails Test	CCTT	8-16	10-14	Llorente, Voigt, Williams, Frailey, Satz, & D'Elia. 2009	PBU	Between .85-.90 for alternate-form reliability	PBU
Comprehensive Trail Making Test, 2nd-edition	CTMT2	8-79	5-12	Reynolds, 2019	N/A	Inhibitory Control Index: .89 Set-Shifting Index: .79 Total Composite Index: .92 (scores available for each	ICI : $r_c = .71$ SSI : $r_c = .69$ TCI : $r_c = .75$ (scores available for each trail, and by age)

					Reliability coefficients		
Test name	**Abbreviation**	**Ages (years)**	**Admin time (min)**	**Source ref.**	**Inter-rater & intra rater**	**Internal consistency**	**Test-retest**
						trail, and by age)	
Drake Musical Aptitude Tests	N/A	8-adult	80	Drake, 1954; Griffin & Eisenman, 1972	N/A	PBU	PBU
Grooved Pegboard Test	GPT	5-8; 9-12; 15+	~3-10	Layfette Instrument Company; Wang et al., 2011	N/A	PBU	0.91 (0.84, 0.95) and 0.85 (0.81, 0.89) for right and left hands, respectively (all $p < 0.001$)
McCarthy Scales of Children's Abilities	N/A	2.5-8.5	45-60	McCarthy, 1972; Levin, 2011	PBU	PBU	PBU
Melodic Ear-To-Hand Test	N/A	Uni age	N/A	Froseth, 2003	N/A	N/A	U of Michigan: .98; U of Indiana: .97 (1985)
Montreal Battery of the Evaluation of Musical Abilities, shortened and full versions	MBEMA	6-8 (9+ take adult version)	20 (shortened version) 30-45 (full version)	Peretz, Gosselin, Nan, Caron-Caplette, Trehub, & Béland, 2013	PBU	PBU	PBU
Musical Aptitude Tests	MATs	7-11	30-40 (2 sessions 15-20 min)	Overy, Nicolson, Fawcett, & Clarke, 2003	NA	NA	NA

					Reliability coefficients		
Test name	**Abbreviation**	**Ages (years)**	**Admin time (min)**	**Source ref.**	**Inter-rater & intra rater**	**Internal consistency**	**Test-retest**
Piano fonics for children	N/A	N/A	N/A	Iabinet, 2005	NA	NA	NA
Piano Lab Music Reading Tests (Sight-Reading component)	N/A	5+	30	Piano Pedagogy Research Laboratory, 2018	N/A	N/A	N/A
Piano Sight-Reading Scale	PSS	11-16	N/A	Lemay, 2008; Watkins & Farnum, 1954	NA	NA	NA
Primary / Intermediate / Advanced Measures of Music Audiation	PMMA / IMMA / AMMA	PMMA: up to 9 (gr. 3) IMMA: 6-9; 10-11 AMMA: 12+	40-50	Gordon, 1979, 1989, GIA Publications	N/A	PBU	AMMA with middle-school students Tonal: .82 Rhythm: .80 Total: .86 (2004)
Processing Speed Index (WISC-V) for Children	PSI	6-16	~12	Babcock, Miller, Saklofske, & Zhu, 2018; Weiss, Saklofske, Holdnack, & Prifitera, 2015; WISC-V, 2014	N/A	PBU	PBU
Purdue Pegboard Test	PPT	5-12, 13-17, 18-64, & 65-89	5-10	Layfette Instrument Company, Podell, 2011; McLellan, 2011; Strauss, Sherman, & Spreen, 2006	N/A	N/A	.76-.89 after 3 trial administration

					Reliability coefficients		
Test name	**Abbreviation**	**Ages (years)**	**Admin time (min)**	**Source ref.**	**Inter-rater & intra rater**	**Internal consistency**	**Test-retest**
Rapid Automatized Naming & Alternating Stimulus Tests	RAN & RAS	5-18	5-10	Wolf & Denckla, 2005	PBU	PBU	PBU
Rhythm Performance Test-Revised	RPT-R	4-12	N/A	Flohr, 2007; 2010	N/A	N/A	N/A
Seashore Measures of Musical Talent	N/A	~4, 10-11, middle school +	N/A	Seashore, 1919; 1939	PBU	PBU	PBU
Stroop or Color and Word Test, Children's Version	SCWT	4-12	~5	Golden, Freshwater, & Golden, 2003	PBU	PBU	all rs > 0.8
Test of Following Oral Directions	TOFOD	5-10	N/A	Gill & Henderson, 2003; Gill, Moorer-Cook, Armstrong, & Gill, 2012	N/A	N/A	r = 0.965, p <.001
Trail Making Test for Older Children	TMT	9-14	>10	Reitan & Wolfson, 1992; 2004; Tombaugh, 2004	PBU	PBU	PBU
Unnamed music reading tests	N/A	9	N/A	Jaarsma, Ruijssenaars, & van den Broeck, 1998	N/A	N/A	N/A
Visual-Spatial Index (WISC-V) for Children	VSI	6-16	~12	Babcock, Miller, Saklofske, & Zhu, 2018; Weiss, Saklofske, Holdnack, & Prifitera, 2015; WISC-V, 2014	N/A	PBU	PBU

Notes: PBU means “published but unavailable”

For each of the identified tests, we reviewed, appraised, and selected them in the following way. First, we reviewed the purpose of the tests to ensure they specifically matched each indicator of dysmusia (screening was kept broadly to manifestations to not exclude any potential tests), Second, we appraised them according to the following criteria which will provide an opportunity for test validation in future studies (Chatterji, 2003):

a) Must be easily administered such that the subsequent trials of the tool can be replicated
b) Must be sensitive to children with learning disorders, as dysmusia might have cognitive, auditory, and motor deficits in common with dyslexia
c) Must have reliability, and validity
d) Must have recent normative data or comparison scores

Our results are summarised in table 5. We used the following acronyms within the table: EA (easily administered), S (sensitive to children with learning disorders), R (reliability), V (validity), and RND (recent normative data).

Table 5

Test Overview, Appraisal, and Selection

Overview			**Appraisal**	**Selection Y/N**
Test Name & Description	**Design/Method**	**Available Normative Data**	**Quality/Comments**	
General Indicator: Slow Processing Speed				
The Comprehensive Trail Making Test, 2nd edition is a test for detecting brain compromise and tracking progress in rehabilitation. Its results are useful for detecting frontal lobe deficits; problems with psychomotor speed, visual search, sequencing, and attention; and impairments in set shifting.	Comprises 5 trails, where the participant: T1: draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle. T2: draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle. Twenty-nine empty distractor circles appear. T3: draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle. Thirty-two distractor circles appear, some empty and some with irrelevant drawings. T4: draws a line to connect in order the numbers 1 through 20, where 11 of the numbers are presented as Arabic numerals and the remaining numbers are spelled out in English-language form. T5: draws a line to connect in alternating sequence the numbers 1 through 13 and the letters A through L, beginning with 1 and drawing a line	Normed on a sample of 1,904 participants from 38 states (2017).	EA: Y S: Y R: Y V: Y RND: Y	Y

Overview			**Appraisal**	**Selection Y/N**
	to A, then to 2, then to B, and so on, until all numbers and letters are connected. Fifteen empty distractor circles appear.			
The Processing Speed Index is a measure of processing speed. The PSI measures the child's speed and accuracy of visual identification, decision making, and decision implantation. Performance on PSI is related to visual scanning, visual discrimination, short-term visual memory, visuomotor coordination, and coordination.	The PSI is derived from the Coding and Symbol Search subtests. Coding (primary, FSIQ) – children under 8 mark rows of shapes with different lines according to a code, children over 8 transcribe a digit-symbol code using a key. The task is time-limited. Symbol Search (primary) – children are given rows of symbols and target symbols and asked to mark whether the target symbols appear in each row.	Updated norms are available for both Canadian and American children Some degree of cognitive variability is typical of most children. Comparisons of a primary index score to an indicator of overall performance can yield information about a child's cognitive strengths and weaknesses.	EA: Y S: Y R: Y V: Y RND: Y	Y
The Stroop or Color Word Naming Test for Children is designed to measure the ability to inhibit a prepotent reading response to engage a naming response.	This version of the Stroop paradigm uses three cards with 100 items each. On the first card, the child is asked to read a list of color words (e.g., red and green) printed in black ink. The second card contains columns of nonword stimuli printed in different colors and the child is asked to name the color of each stimulus. On the final card, color words are printed in colors different from the word (e.g.,	The authors of the test manual present little psychometric data regarding the use of the test in samples of children. The manual indicates that the test–retest reliability of the Stroop paradigm is fairly robust across test versions. MacLeod	EA: Y S: Y R: Y V: Y RND: N	N

Overview			**Appraisal**	**Selection Y/N**
	blue printed in green ink) and the child is required to name the color instead of the word.	(1991) suggests that, across all ages and versions, the Stroop paradigm displays good validity. (Moran & Yeates, 2011)		
The Rapid Automatized Naming & Alternating Stimulus Tests are individually administered measures designed to estimate an individual's ability to recognize a visual symbol such as a letter or color and name it accurately and rapidly.	The tests consist of rapid automatised naming tests (Letters, Numbers, Colors, Objects) and two rapid alternating stimulus tests (2-Set Letters and Numbers, and 3-Set Letters, Numbers and Colors). The Letters, Numbers, Colors, and Objects tests are comprised of five high-frequency stimuli that are randomly repeated ten times in an array of five rows for a total of fifty stimulus items. The 2-Set Letters and Numbers and 3-Set Letters, Numbers, and Colors tests are comprised of 10 and 15, respectively, high-frequency stimuli that are randomly repeated in an array of five rows for a total of fifty stimulus items.	The tests were normed on 1,461 individuals in 26 states; these norms are suitable for individuals from ages 5 through 18.	EA: Y S: Y R: Y V: Y RND: Y This is a text reading test and is less relevant to music reading.	N
The Trail Making Test (TMT) is a widely used test to assess executive abilities in patients with stroke. Successful performance of the TMT	The Trail Making Test consists of two parts (A and B), each of which contains 15 circles distributed on a sheet of paper. In Part A, each circle contains a number from 1 to 15, and after the subject completes a sample	Normative data is available for adults, but not for children.	EA: Y S: Y R: Y V: Y RND: N	N

Overview			Appraisal	Selection Y/N
requires a variety of mental abilities including letter and number recognition mental flexibility, visual scanning, and motor function.	of the test, the child is instructed to begin at the number 1 and to locate and draw a pencil line to 2, then to 3, and so on until reaching the number 15. Part B has both numbers and letters within the 15 circles, and the subject is instructed to alternate between them as the numerical and alphabetical sequences progress. The child begins at 1, locates and draws a line to A, then to 2, then to B, and so on until completing the test.			
General Indicator: Difficulty Following Lesson Instructions				
Test of Following Oral Directions: To develop a criterion referenced measure for following directions that contains linguistically controlled functional directives to help pinpoint exactly where a child's direction following skills break down.	The test administrator arranges 20 common objects on a table in front of the child. Verbal instructions are given to the child. Level one contains simple instructions. Level two contains complex instructions.	Preliminary analyses suggest that the instrument offers a reliable tool for typically developing children; however, this should be interpreted with caution because results might differ for children who are highly distractible or inattentive. Only one measure of reliability was performed. Preliminary analysis suggests that the TOFOD is reliable in test-retest applications for children with typical language. A	EA: Y S: ? R: Y V: Y RND: Y	Y

Overview			**Appraisal**	**Selection Y/N**
		second limitation to the study is that the TOFOD was administered only to children with typically developing language.		
General Indicator: Poor Concentration				
See: CTMT-2				Y
Children's Color Trails Test: Is an individually administered, orthographic (paper and pencil), neuropsychological instrument designed to provide an objectively scored measure of sustained visual attention, sequencing, psychomotor speed, and cognitive flexibility.	The CCTT retains many similarities to the original children's version of the Trail Making Test (TMT), but substitutes the use of colour for the use of letters from the English alphabet.	Normative data is available in the manual for the test.	EA: Y S: Y R: Y V: Y RND: Y	N
General Indicator: Forgetting Note Names				
See: Music Reading				Y
General Indicator: Poor Auditory Skills: Audiation				
Primary, Intermediate, or Advanced Measures of Music Audiation: To provide objective music aptitude scores to inform teachers and parents of	PMMA consists of two subtests, Tonal and Rhythm. Each includes practice and 40 paired test questions. IMMA consists of similar tests to PMMA, though difficulty is increased. AMMA is similar to	Has validity and reliability	EA: Y S: Y R: Y V: Y Recent normative data: Y	Y

Overview			**Appraisal**	**Selection Y/N**
students' educational progress.	IMMA and PMMA, though difficulty is increased		-Has been used in studies of children with dyslexia (Forgeard et al., 2008; Steinbrink et al., 2019)	
Montreal Battery of the Evaluation of Musical Abilities: Can serve as an objective, short, and up-to-date test of musical abilities in a variety of situations, from identification of children with musical difficulties to assessment of the effects of musical training in typically developing children of different cultures	It contains contour, interval, scale, rhythm, and memory tests. All tests use the same 20 unfamiliar tonal melodies, in 10 different keys (half major, half minor). The melodies, (5-9 tones long in overall duration) are computer-generated, each presented in a different timbre or instrument.	Normalised in samples of Canadian children (English- and French-speaking) and Chinese children (Mandarin-speaking). Tests have validity and reliability	E: Y S: ? R: Y V: Y R: Y -Older children (9 years old and older) would take the adult version of the test, which has a longer administration time.	N
The Rhythm Performance Test-Revised: Is a computer-based test instrument designed to assess performance of steady beat and rhythm patterns by children.	RPTR assesses skills across two domains:1) matching the steady beat of recorded examples and 2) listening to and repeating rhythm patterns.	It is a standardized, norm-referenced instrument that measures rhythmic performance to an accuracy of milliseconds.	EA: ? S: ? R: Y V: Y RND: Y -Published but unavailable test.	N
Musical Aptitude Tests: To test musical timing skills in a	Tests of rhythm (copying, discrimination, song rhythm), metre (tempo copying, tempo	The results of the MATs showed an overall trend for the dyslexic group to	EA: ? S: Y R: Y	N

Overview			**Appraisal**	**Selection Y/N**
population of children with dyslexia	discrimination, song beat), rapid skills (note order detection, note number discrimination), pitch (melody discrimination, pitch discrimination, pitch matching), & other (song, timbre discrimination, musical experience)	score lower than the control group on the tasks involving timing skills (as predicted), and higher than the control group on the tasks involving pitch skills (which was not predicted).	V: ? RND: N -Nonstandard published measures; unavailable test -Small sample size (n = 16 with dyslexia, n = 18 without dyslexia) -Limited number of items per test	
Drake Musical Aptitude Tests: To measure the fundamental components of musical aptitude: musical memory and rhythm	Musical memory subtest is similar to a digit-span test in an IQ test: participant responds to possible changes in time, key, or notes Rhythm subtest requires the participant to maintain a pre-determined tempo for varying periods of time	Low intercorrelations between the subtests suggest that musical aptitude is not a unitary trait. High correlations between subtest scores and music teachers' ratings of musical talent	EA: ? S: ? R: Y V: Y RND: N -Nonstandard published measures -Questionable validity and reliability	N
Seashore Measures of Musical Talent: To test the assumption that musical talent exists in children	A series of listening tests pertaining to sense of 1) pitch, 2) intensity; a series of motor tests measuring 1) timed action, 2) rhythmic action, 3) motility, 4) singing in pitch	Seashore created a Talent Chart based on norms and percentile rank values for children in the fifth grade and eighth grade as well as adults. Each test would be normed and given a percentage value.	EA: ? S: ? R: Y V: Y RND: N -Nonstandard published measures -Questionable validity and reliability	N
Melodic Ear-To-Hand Test: The test is a measure of one's ability	It comprises 100 tape recorded melodic patterns organised into nine sequences of progressive difficulty.	Normative data exists (Cohort of 100 first-year	EA: ? S: N R: Y	N

Overview			**Appraisal**	**Selection Y/N**
to performance diatonic melodic patterns "by ear" on the major/principal instrument.		undergraduate music students in 1982)	V: Y RND: N -Nonstandard published measures -Questionable validity and reliability -No data available for how this can be administered to children	
Music Reading				
Piano Lab Music Reading Tests: To measure accuracy in note recognition/decoding, and pattern decoding in children and adolescents, particularly children who have learned to read music following an intervallic approach.	There are three categories of tests: 1) Single Note Recognition (Piano Keyboard, Treble Clef, & Bass Clef); 2) Pattern Notes (2-note intervals [solid & broken], 3 note-intervals, on C position and G position); 3) Sight-Reading (1 performance only and note naming, 2 with performance-rehearsals-final performance)	Data is available on a cohort of over 100 children tested in 2018-2019	EA: Y S: ? R: N V: N RND: N -recent group means available -Unpublished measures	Y
Piano fonics for children: SightPlay Solutions is an in-lesson instructional tool for teachers to use with beginning students to prevent reading comprehension problems – or with	It provides early experiences with the structure and function of music notation. The structure consists of ten Guide Notes – their keyboard location in direct correlation with their Grand Staff position. the function of music notation relates keyboard (hand) with staff (eye).	There is no quantitative data. assessment is informal, when a student meets or fails to complete a task is at teachers' discretion.	EA: ? S: ? R: N V: N RND: N -Nonstandard test	N

Overview			**Appraisal**	**Selection Y/N**
students to improve reading skills. It provides a framework for music reading skills to evolve and is a tool for diagnosis and remediation of reading problems.				
Unnamed music reading tests: To gain more insight into the possible difficulties children with dyslexia experience when they learn musical notation.	8 assignments: 1) Learning a series (of notes); 2) Recognising notes within composition; 3) Reviewing notes from a previous series; 4) Combining previously learned notes; 5) Drawing notes whose names were under the staff or read aloud; 6) Naming notes shown on a large chart, or finding the corresponding note cards; 7) Testing ready knowledge of note names with flash cards; 8) Evaluation of what the child considered difficult/easy.	During the sixth assignment of the second session, children had to choose two to five cards whose graphic representation matched the notes pictured on a large chart. During 70 trials, they made a total of 18 mistakes (26 percent) of which about 30 percent were third transpositions.	EA: ? S: Y R: N V: N RND: N -Nonstandard test, with a very small population, with no materials available.	N
Piano Sight-Reading Scale: "We will develop a sight-reading measurement scale for pianists that will be adapted from the Watkins-Farnum Performance	11 exercises of increasing difficulty, from beginner to ARCT level.	No problems or concerns came out of the measurement with the PSS. The assessment of performances with the PSS involved a straightforward and reasonably timed process, lasting approximately two hours.	EA: Y S: ? R: N V: N RND: N -Nonstandard published test. Small participant sample	N

Overview			Appraisal	Selection Y/N
Scale for woodwind players." (Lemay, 2008, p. 32)		The two testers had a few inconsequential queries.		
Sequencing				
Aural Memory *See: PMMA / IMMA / AMMA*				Y
Visual-Motor Memory *See: CTMT-2*				Y
The Clock Drawing Test for Children: The clock drawing test has been found to be sensitive to visual–spatial perception, graphomotor skills, verbal reasoning, and executive functioning in adult patient populations, as well as frontal lobe maturation in normal children.	13-point scale for clock construction and a 5-point scale for setting the appropriate time.	Normative sample data from Cohen et al. (2002) from 429 typically developing children ages 6-12 years.	EA: Y S: Y R: Y V: Y RND: N	N
Eye-hand Coordination				
Purdue Pegboard Test: The original application for the test was for testing the dexterity of industrial workers. It has been since used for testing of dexterity	Five batteries: 1) right hand, 2) left hand, 3) both hands, 4) right + left + both hands (sum rather than an actual test), 5) assembly	Available norms for the following age groups: 6-12, 13-17, 18-64, & 65+	EA: Y S: Y R: Y V: Y RND: Y	Y

Overview			Appraisal	Selection Y/N
testing within various populations in the clinical setting.				
Grooved Pegboard Test: This procedure measures performance speed in a fine motor task by examining both sides of the body, inferences may be drawn regarding possible lateral brain damage.	This manipulative dexterity test contains twenty-five holes with randomly positioned slots and pegs which have a key along one side. Pegs must be rotated to match the hole before they can be inserted.	Available norms for: Ages 5 years 0 months to 8 years 12 months; 9 years 0 months to 14 years 12 months; 15 years 0 months and above	EA: Y S: Y R: Y V: Y RND: Y -While this test also has recent information, the PPT has more specific subtests relative to each hand.	N
Visual-Spatial Ability				
Visual-Spatial Index: The VSI is a measure of visual spatial processing.	The VSI is derived from the Block Design and Visual Puzzles subtests. These subtests are: Block Design (primary, FSIQ) – children put together red-and-white blocks in a pattern according to a displayed model. This is timed, and some of the more difficult puzzles award bonuses for speed; Visual Puzzles (primary) – children view a puzzle in a stimulus book and choose from among pieces of which three could construct the puzzle.	Updated norms are available for both Canadian and American children.	EA: Y S: Y R: Y V: Y RND: Y	Y
McCarthy Scales of Children's Abilities: Are designed as an	It contains 18 subtests that compose six scales. The Verbal Scale measures maturity of verbal concepts	Norms mirrored the 1970 US census data and	EA: N S: Y R: Y	N

Overview			**Appraisal**	**Selection Y/N**
individually administered test of intelligence for children between the ages of 2½–8½ years of age.	and includes tests of Pictorial Memory, Word Knowledge, Verbal Memory, Verbal Fluency and Opposite Analogies. Taken together, the scale is thought to measure the ability to comprehend verbal information and to express oneself through language. The Perceptual-Performance Scale measures nonverbal reasoning ability and visual-motor coordination. Its seven subtests include Block Building, Puzzle Solving, Tapping Sequence, Right-Left Orientation, Draw-A-Design, Draw-A-Child and Conceptual Grouping. (Levin, 2011).	1,032 children were tested.	V: Y RND: N	
See: The Clock Drawing Test for Children				N

Discussion

The aim of this paper was to select tests relevant to the manifestations and indicators of dysmusia as an intermediate step in developing a screening tool. In summary, we selected the following seven tests: *The Comprehensive Trail Making Test, 2nd edition, The Processing Speed Index, The Test of Following Oral Directions, The Primary, Intermediate, or Advanced Measures of Music Audiation, The Piano Lab Music Reading Tests, The Purdue Pegboard Test*, and *The Visual-Spatial Index*. The only manifestation for which there are no tests is Music Writing. Our expectations to find tests for music-specific manifestations (music reading, music writing) and the general indicator of auditory skills, tended to be small given that several tests for children were developed in dissertations several decades ago but never standardised (see Colwell, 2019 for a review). However, for the non-music-specific general indicators (processing speed, difficulty following lesson instructions, poor concentration) and manifestations shared with dyslexia (eye-hand coordination, visual-spatial ability), we expected a large test selection due to the body of research that exists for dyslexia and related learning disorders.

General Indicators

We expected that that we would find many tests measuring processing speed in children, because it is commonly evaluated in research and clinical practice of learning disorders including dyslexia (Nelson, 2009). Examples in research include tests that are simple (e.g., reaction time) and complex (e.g., information processing). In clinical practice, intelligence tests such as the *Wechsler Intelligence Scale for Children* (WISC) are used most often. Broader use clinical tools include puzzle-piece matching (Alvino, 2008; Dossett, 2001) though there is inconsistency about how these tests are administered. Our selection of the *PSI* is based on its typical inclusion in psychological assessments of children with dyslexia (Stefanak et al., 2019). The *CTMT2* differs from the WISC as it measures psychomotor processing, a type of processing speed denoting the time it takes to complete repetitive motor tasks (Cepeda, Blackwell, & Yuko, 2013). Because music reading involves a motor component, the *CTMT2* serves as a complement to the *PSI*. We expected to find many tests for following lesson instructions because a common deficit in dyslexia is online comprehension of what is being written or spoken[8] (Vellutino et al., 2004). However, we found two barriers to access tests for following instructions: variance and availability. There is variance among tests used due to what is operationalised such as specific linguistic elements (Gill, Moorer-Cook, Armstrong, & Gill, 2012), working memory (Jaroslawska, Gathecole, Allen, & Holmes, 2016), and instruction type (Sy, Donaldson, Volimer, & Pizarro, 2014). Regarding available tests that fit our criteria, we found only the *TOFOD*. We expected to find many tests for concentration, because it is a common problem among school-aged children with dyslexia (Faught, 2006; Snowling, 2013). However, only three fit our criteria: The *CTMT2*, *The Children's Color Trails Test*, and the *Stroop Test*. According to Mitrushini (2005), these are the most common attention and concentration tests used in psychology. We found overlap between available tests for poor concentration and slow processing speed. Given that the *CTMT2* has index scores for inhibitory control and set-shifting, which accounts for both processing speed and attention, it was an ideal selection for both general indicators. For music audiation, we expected to find many tests since it is addressed in studies of students with

[8] "[Reading] is a complex process that depends on adequate development of two component processes: word identification and language comprehension. […] Language comprehension involves integrations of the meanings of spoken or written words in ways that facilitate understanding and integration of sentences in spoken or written text in the interest of understanding the broader concepts and ideas represented by those sentences" (Vellutino et al., 2004, p. 5).

dyslexia learning music (Forgeard et al., 2008; Overy, 2000; 2003; Overy et al., 2003; Steinbrink et al., 2019), in musicians with dyslexia (Bishop-Lieber et al., 2014), and in studies of children with phonological difficulties (Anvari et al., 2002; Besson et al., 2007; Grube et al., 2014). However, only Gordon's *Measures of Music Audiation* (1979; 1989) met all selection criteria.

Music Reading

We expected to find few music reading tests with children, as the study of music reading development with this age group is relatively new (Gudmunsdottir, 2010). To date, music reading with respect to dyslexia in children has been limited to note identification studies (Flach, Timmermans, & Korpershoek, 2016; Jaaersma, Ruijssenaars, & Van den Broeck, 1998) with no materials available for replication. However, there has been interest in diagnosing music reading difficulties in the context of decoding at an instrument (Cuddy & Hébert, 2006; Iabinet, 2005). *The Piano Lab Music Reading Tests* are relevant to both note identification and note decoding indicators of dysmusia. Given that no other tests in the literature met all test selection criteria, these tests are the best fit given their relevance to the indicators being measured.

Reporting that the score appears differently. We did not expect to find tests pertaining to the score appearing differently, because these may be indicators of visual problems, which would require an optometrist's evaluation for measurement rather than a test for use by the generation population (Oglethorpe, 2002). A study by Atkinson (1993) suggested a relationship between dyslexia, music reading, and visual problems in a subgroup of children with dyslexia but this was only a pilot study and has not been replicated to date. While tests for vision problems are not feasible to include in the first screening tool because of the requirement of an optometrist's evaluation in addition to the other tests, perhaps subsequent studies of dysmusia could include it.

Sequencing

We expected to find sequencing tests for auditory memory because in the music domain, music and memory is studied in populations of adult musicians and non-musicians (Brown & Palmer, 2012; Cohen et al., 2011), and in dyslexia diagnosis, both auditory and visual memory are evaluated (Vellutino et al., 2004). Our previous study revealed musicians reported sequencing difficulties during aural play or singback exercises as well as when memorising a pattern on their instrument from the score (a visual cue). For aural play or sing back, musicians reported forgetting notes (Ganschow et al., 1994; Miles, 1996) and for memorising a pattern from a score, musicians reported this was a slow and laborious process compared to peers (Ganschow et al., 1994; Nelson 2014; Lea, 2001, 2008). Thus, we required two tests, one for auditory memory (music) and one for visual-motor memory. The Gordon Measures of Music Audiation will test for auditory memory (discerning meaning of patterns of notes and beats), and the CTMT2 will test for visual-motor memory (psychomotor speed).

Eye-Hand Coordination

We expected to find a variety of tests for eye-hand coordination, both because it has been explored in populations of adult professional musicians vis-à-vis the relationship between musical score and eye-hand coordination (Sloboda, 1974) as well as in children learning music through off-staff training such as the Orff method (Martins et al., 2018). The literature on tests for eye-hand coordination in motor control includes pin and board tests (e.g., *The Purdue Pegboard Test* and the *Grooved Pegboard Test*), programmable tablets (Brandes-Aitken et al., 2018; Culmer, Levesley, Mon-Williams, & Williams, 2009; Domkin, Sörqvist, & Richter, 2013; Hill, Culmer, & Mon-Williams, 2014; Lazzarri, Mottet, & Vercher, 2009; Lee, Junghans, Ryan, Khuu, & Suttle, 2014), and eye-tracking studies (Rayner, 1978; 1998). Of these options, pegboard tests are the only type that fit our accessibility criteria. We selected the *Purdue Pegboard Test*, which, in addition to meeting our criteria, is often administered alongside the *WISC*, because motor skills could be linked to cognitive abilities (Pangelinan et al., 2011).

Visual-Spatial Ability

In our previous study, musicians referred to difficulties discerning left from right in terms of their hands and the score. This visual-spatial difficulty is common to dyslexia, where the brain has difficulty situating objects relative to each other in space (Rein, n.d.). We expected to find many tests, however, several were either outdated such as the *McCarthy Scales* (Levin, 2011; McCarthy, 1972), or non-standardised (e.g., Rendine, 2009; Sidor, 2010). We selected the *VSI* index which is used in assessment of dyslexia (Giovagnoli et al., 2016) because dysmusia might share similar visual-spatial deficits with dyslexia.

Developing Music Writing Tests

There are no available music writing tests. Concurrently with our investigation of dysmusia, we developed music writing tests intended for children, *Piano Lab Music Writing Tests*, using the same stimuli as the music reading tests to facilitate comparison of results. The purpose of these tests was informed by the indicators of messy writing and difficulties with dictation, which could be measured with copying and dictation tests, respectively. In the copying test, participants view stimuli on a computer screen, in the form of quarter notes on the treble clef. They are instructed to copy the notes on staff paper in front of them and are given a new piece of staff paper for each trial. In the dictation test, participants are instructed to listen to the administrator verbally name notes aloud, and then write the notes as quarter notes on staff paper in front of them. They are given a new piece of staff paper for each trial. This is a modified form of dictation as it is typically understood to be writing notes with aural stimuli from an instrument (e.g., piano). We modelled our tests after the copying and dictation tests by Re and Cornoldi (2015) which assessed the types of writing errors of children with dyslexia and ADHD. Their copying and dictation tests used texts of about equal difficulty, with the same number of word characteristics and complexity. Their categories for error assessment included: phonological, non-phonological, or refinement (e.g., double letters or incorrectly placed accents). To facilitate a comparison with our music reading tests, we adopted the same marking scheme, with a few additions specific to evaluate music writing.

Feasibility Considerations

Upon test selection, we conducted a pilot study with six musicians to determine how our chosen tests worked in practice. Participants included two children (ages 7 and 10), one adolescent (age 14) and three adults. We found that the trail making test had clearer instructions and a shorter administration time compared to the PSI subtests, and decided to remove the latter. Regarding the VSI, we noticed that the younger participants had a wide variance in completion time, and the VSI has strict cut off points for stimuli. We opted to make our own tests that focused on correct task completion, because we are exploring if children can complete tests correctly and accurately, instead of within a certain time constraint. Finally, we noticed that all pilot participants struggled with the TOFOD, frequently asking the administer to repeat instructions, or completing instructions out of the instructed order. Thus, we cut it out of the initial tool.

Conclusion

Developing a screening tool for dysmusia required consideration of available tests as this has been done in the music domain for amusia and in the text domain for dyslexia and related learning disorders. Informed through our critical review of music, cognitive, and motor tests, we selected seven tests specific to dysmusia's manifestations and indicators that can be used with a population of children learning music. To accomplish this, we first performed a systematic search based on the STARLITE method (Booth, 2006) to purposefully generate a list of tests relevant to manifestations and indicators. Second, following common practice in screening tool development, we specified both inclusion criteria for test review as well as selection criteria for the proposed screening tool (Chatterji, 2003). Selection criteria included ease of administration, recent normative data, reliability, validity, and sensitivity to populations with learning disorders. We discussed how expectations for test selection varied depending on whether the test was for a music specific manifestation or indicator or part of a possibly shared manifestation or indicator with dyslexia. The only manifestation unaccounted for in the review is music writing because our search yielded no results. We suggested adapting writing tests for children with dyslexia that could allow us to explore characteristics of music students' writing errors. Following test selection, we piloted them with children and adults, leading to the removal of PSI, VSI, and TOFOD, and addition of modified puzzle and visual tasks meant for exploration and not diagnosis. With our selection of existing tests and development of preliminary music writing tests, the next step in screening tool development is to explore how a population of young piano students along a spectrum of music reading competencies perform, with the goal of continued screening tool refinement.

Limitations

We acknowledge the following limitations to our study. First, as dysmusia is a new avenue of research in music pedagogy, there is a lack of previous research studies on the topic of dysmusia and no existing screening tools for comparison. Typically, reviews to develop new screening tools for a phenomenon include existing tests and show gaps in what those tests can measure. As our proposed tool will be the first to identify possible tests, our review differed by including tests for each manifestation and indicator. This could also be interpreted as a strength of our review, as we considered dysmusia from every angle it could affect in a variety of fields (music, education, psychology, and motor control). Second, given our selection criteria (accessible, easy to administer, have normative data, and sensitive to children with learning disorders), our proposed screening tool excludes several tests that are out of scope. For example, tests that were developed in unpublished doctoral dissertations were likely of high quality, but not having access to the test materials and not having information about normative data, reliability, and validity would put into question the replicability of our proposed tool. Regarding ease of administration, we found that several tests for eye-hand coordination and visual-spatial ability required complex apparatus and protocols that would not appeal to a broader range of research groups aiming to replicate our tool. Given that our screening tool will only suggest dysmusia and not diagnose it, our decision to follow specific inclusion criteria will eventually allow for research groups to refine the tool. Finally, our search revealed no music writing tests, requiring that we add our own to account for all the manifestations of dysmusia. Since there were no music writing tests that were identified in the data that met our selection criteria, our current tests are provisional and will be refined over time. Furthermore, they can reveal characteristics of writing errors that can be further studied.

Pedagogical Implications

Our proposed screening tool for dysmusia contributes to the pedagogical community at the researcher, music teacher, and music student levels. Researchers can use our screening tool for further refinement and validation. We have selected tests that are accessible within the scientific community and are easily replicated. With future dissemination of knowledge pertaining to dysmusia and testing, music teachers can arrange for screening sessions with their students. The results of these sessions will help teachers better accommodate their students with customised music lessons that address the challenges revealed through the screening tool. Finally, music students will benefit from the screening tool because of customised pedagogy suited to their needs. Their music learning experience will be enriched leading to lower rates of attrition and more opportunities for long-term musical pursuits.

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Chapter 4: Creating a screening tool for dysmusia: Establishing a baseline for music reading, music writing, and audiation tests with young pianists[9]

Abstract

Framed as a possible extension of dyslexia, the phenomenon of dysmusia has yet to be measured in a population of young piano students. We do not know the average test performance of young piano students with neither dysmusia nor dyslexia, or how test performances interact. Combined, this information could create a baseline. Our study had two aims: first, to calculate the mean test performance among piano students on music reading, music writing, and audiation tests, and second, to explore relationships between reading and writing, and reading and audiation test performance. Results for test relationships showed that music reading and writing test performance is dependent on the challenge of each task. Sight-reading proficiency does not affect audiation performance in a statistically significant way. However, visual inspection of results shows that rhythm performance distribution is more varied compared to tonal performance.

Keywords: dysmusia, dyslexia, music reading, piano students

[9] Submitted to *British Journal of Music Education*

Background

Dysmusia, a phenomenon in music pertaining to difficulties in music reading, could either be an extension of dyslexia or its own entity separate from dyslexia as suggested by Cuddy and Hébert 2006).[10] Over recent decades, it has been suggested that dysmusia could be a contributing factor to difficulties in music reading acquisition (Gordon, 2000). We take the position that dysmusia and dyslexia are related, thus having similar patterns of difficulties. Through a qualitative review of reports from musicians and music teachers reporting and observing music reading difficulties, we found several musicians noting that sight-reading was particularly challenging (Authors, 2022a). We sorted the musicians' specific difficulties (referred to as indicators) into larger groups of related difficulties (referred to as manifestations) according to the British Dyslexia Association's (BDA) framework (n.d., "Signs of Dyslexia"). In addition to music reading, manifestations of dysmusia include music writing, music sequencing, eye-hand coordination, and visual-spatial ability. Of these manifestations, we found several sources indicating cooccurrences of music reading and writing difficulties among musicians with a dyslexia diagnosis (Apostoli, 2008; Bishop-Liebler, 2008; Nelson, 2014; Poole, 2001; Smith, 2001; Solook, 2016; Wade, 2006). Furthermore, dysmusia possibly shares an auditory processing deficit with dyslexia. However, where dysmusia can be unique from dyslexia is at the level of audiation, because our review (Authors, 2022a) found that that while several musicians reported difficulties with music reading and audiation (Bishop-Liebler, 2008; Lea, 2001; Oldfield, 2001; Vladokovic, 2013), numerous others did not, though it is unclear whether the difficulties were

[10] "[Musical dyslexia] is a difficulty with learning to read music despite normal intelligence and opportunities [which] should be identifiable and should exist as an entity separate from text dyslexia" (Cuddy & Hébert, 2006, p. 203).

existent but unreported. Finally, we found that most reports were pertaining to children in the early stages of learning piano.

Reading, writing, and auditory performance relationships in language

There are relationships between reading and writing, as well as between reading and auditory skills in language acquisition research (Abramson & Lloyd, 2016; Lukács et al., 2021; Peterson et al., 2015; Ray et al., 2021; Snowling, 2013; Snowling et al., 2018; Witton, Swoboda, Shapiro, & Talcott, 2020). Difficulties with reading or lack thereof influence performance on writing and auditory discrimination. Studies show that children without dyslexia develop reading and writing fluency at similar rates from kindergarten onwards and this is due to successful integration of reading, transcription, and oral language skills (Kent et al., 2014; Ray et al., 2021).

Compared to controls, children with dyslexia experience delays in producing letters throughout childhood in both letter copying and dictation tasks (Alarmogot, Morin, & Simard-Dupuis, 2020; Jones & Christensen, 1999; Pontart et al., 2013; Re & Cornoldi, 2015). Similarly, compared to controls, children with dyslexia particularly struggle with auditory discrimination, especially for pitch (Snowling et al., 2018; Wehner, Ahlfors, & Mody, 2007; Witton, Swoboda, Shapiro, & Talcott, 2020). However, the difference between auditory skills between individuals with and without dyslexia is impacted by musical training induced neuroplasticity (Schlaug et al., 2009; Weiss, Granot, & Ahisser, 2014; Zuk et al., 2017). We do not know if a participant group of young piano students with varied proficiency in music reading would have similar audiation performance. To explore this relationship, we would need a measure of music reading proficiency, such as sight-reading performance.

Research Problem

Our understanding of the phenomenon of dysmusia is based on a review of available literature about manifestations and indicators experienced by the musical community. As such, there is no empirical way to test for dysmusia, though with laboratory developed tests for music reading and writing, as well as with a standardised audiation test, we could contribute to the development of a baseline against which suspected cases of dysmusia could be compared (Authors, 2022b). Furthermore, understanding how the music reading and music writing, and music reading and audiation tests interact in a population of young piano students without dysmusia could inform how we interpret results of populations with dysmusia. In language literature, there is a link between text reading and writing performance, as well as between text reading and audiation performance (Abramson & Lloyd, 2016; Lukács et al., 2021; Witton, Swoboda, Shapiro, & Talcott, 2020), but this link has not been tested with respect to music.

The purpose of this study is to create a baseline for music reading, music writing, and audiation tests for dysmusia through two ways: first, by calculating group means for each test, and second, by comparison of test performances to each other, in a group of young piano students without dysmusia. The results of calculating mean scores would create a control group, to which test performance for cases of dysmusia can be compared. Results of comparing test performance would give us an expectation of how we could expect scores to relate to each other in further studies. Including piano students ranging in music sight-reading proficiency gives us the opportunity to explore, in the case of audiation, how performance can change with more advanced reading achievement. As this is the first study to quantifiably measure music reading, music writing, and audiation for the purposes of creating a screening tool for dysmusia, further studies can replicate our findings to strengthen the baseline data.

Research Questions and Hypotheses:

Given that dysmusia has yet to be empirically measured in children, a first step is to establish a baseline in non-dysmusic children through both calculating test means as well as exploring how the test performances relate to each other. As literature in language suggests that reading and writing, and reading and audiation are related, we can explore if this could also be true for non-dysmusic children. In this way, we have a clearer idea of what to expect in suspected cases of dysmusia. Our primary research question is, what is the mean test performance for music reading, music writing, and audiation in a group of young piano students without dysmusia? Our secondary research question is divided in two parts: are test results for music reading and writing the same on paired conditions, and are test results for audiation the same across our participant sample with both low and high proficiency sight-readers? Regarding research question 1, we hypothesise that test means would be higher for participants more advanced in their musical training compared to beginner participants. Regarding research question 2 for music reading and music writing, we have a null hypothesis, which is music reading and writing test performances are the same, H_0: median difference = 0. This is because in language, reading and writing performance is the same in populations with and without dyslexia. Regarding research question 2 for music reading and audiation, we have a null hypothesis, which is that music reading proficiency, as determined by a sight-reading measure, does not affect audiation performance, H_0: median difference = 0.

Method[11]

Design

For research question 1, we divided our participant sample into two groups: beginner and intermediate-advanced. We calculated group means for music reading, music writing, and audiation tests. For research question two, we used a paired sign test design for the music reading and writing test, as each test had 1-note, 2-notes, and 3-notes conditions. The independent variables were the paired music reading writing test conditions. The dependent variables were the test performances. To compare piano students with varying sight-reading proficiency across parameters of an audiation test, we selected a Mann-Whitney test (differences between two independent groups). The dependent variables were the composite (overall), tonal, and rhythm percentile rank scores obtained by the participants on school-grade dependent listening tests.

Materials

Our study comprised four test groupings: music reading divided into lab developed tests and sight-reading, music writing (copying and dictation) and Gordon's Measures of Music Audiation; the version of the audiation test administered was dependent on the participants' school grades (Gordon, 2001). Brief test descriptions are outlined in table 1.

Table 1

Brief Test Descriptions

Group	Tests	Subtests	Measurements
Music reading	*Lab developed*	• 1-note identification (treble clef) • 2-notes pattern playing (C	Input from Musical Instrument Digital Interface (MIDI) and manual data entry from video recording.

[11] Refer to Chapter 8: Appendices, for materials discussed in this chapter.

Group	Tests	Subtests	Measurements
		position, treble clef) • 3-notes pattern playing (C position, treble clef)	Scored as correct/incorrect.
	Sight-reading	• 8 progressively challenging, short piano pieces	Test administrator cuts off participant when they make several mistakes per bar. Scored manually according to our lab developed sight-reading scale. Points are deducted for pitch, rhythm, and expression mistakes.
Music writing	*Copying*	• 1-note copying (treble clef) • 3-notes copying (treble clef)	Scored manually on two levels: noteheads, and descriptive errors to generate a total score.
	Dictation[12]	• 1-note dictation (treble clef) • 2-notes dictation (treble clef)	Scored manually on two levels: noteheads, and descriptive errors to generate a total score.
Measures of Music Audiation	*Primary (Kindergarten – grade 2)*	• Tonal test • Rhythm test	Computer scores given for tonal (PR), rhythm (PR) and composite (PR)
	Intermediate (Grade 3 – 6)	• Tonal test • Rhythm test	Computer scores given for tonal (PR), rhythm (PR) and composite (PR)
	Advanced (Grade 7 up)	• 1 test including both tonally and	Computer scores given for tonal (PR),

[12] The dictation test involves the administrator verbally instructing the participant to write specific notes on staff paper. We consider this a modification to typical musical dictation which involves the participant writing notes based on aural stimuli played by an instrument (e.g., piano). This decision was based on the educated assumption that few participants who are beginner students would have experience with typical dictation.

Group	Tests	Subtests	Measurements
		rhythmically manipulated stimuli	rhythm (PR) and composite (PR)

Participants

We recruited 24 piano students for the study ranging in age from 5.8 – 15.9 years and in music playing experience from beginner to advanced players. No participants had a diagnosis of dyslexia for text reading. Male (*n* = 11) and female (*n* = 13) participants were represented in all music playing levels. On average, participants had been in music lessons for 5.45 years (as reported by parents) and had been music reading for approximately 4.5 years (as reported by piano teachers). We should note that five participants indicated their left hand was preferred for writing activities. Participants' music learning methods included: Royal Conservatory of Music (RCM) (Frederick Harris Music, 2015), Conservatory Canada (Conservatory Canada, 2014), Suzuki Piano School (Azuma, 2008), Yamaha Piano Method (https://ca.yamaha.com/en/education), L'école de musique Vincent-d Indy (https://www.emvi.qc.ca/), Piano Adventures (Faber & Faber, 1996), and Alfred's Basics Piano Course (Palmer, Manus, and Lethco, 1981). For a demographic summary, see table 2.

Table 2

Summary of Participant Demographic Information

Gender	Age	Level	No. years reading music	No. years in music lessons
Overall				
M: *n* = 11 F: *n* = 13	Range: 5.8 – 15.9 Mean: 11.46 Median: 12.2	Beg.: *n* = 13 Int-Adv. *n* = 11	Mean: 4.5 Median: 4	Mean: 5.45 Median: 5
By music level				
Beginner				
M: *n* = 7 F: *n* = 6	Range: 5.8-15.1 Mean: 10.65 Median: 10.3	*n* = 13	Mean: 3.3 Median: 3	Mean: 4.15 Median: 5
Intermediate-Advanced				
M: *n* = 4 F: *n* = 7	Range: 10.4 – 15.9 Mean: 13.3 Median: 13.3	*n* = 11	Mean: 5.9 Median: 6	Mean: 7 Median: 6.5

Procedure

We obtained ethics approval through our academic institution. Through an invitation letter sent to music teachers and music schools, we invited piano students and their parents to participate in our study. At the date of testing, all participants and parents filled assent and consent forms, and after testing was completed, they filled out debriefing forms. While the piano students participated in the music activities, the parents filled out a motivation questionnaire about demographic information, music, and learning. The order for test administration was music reading, music writing, audiation for children ages 5-9, and the writing and auditory tests were reversed for participants ages 10-15. While the audiation test is recommended to take place on separate days for tonal and rhythm parameters, it was impractical to schedule multiple sessions per participant. Thus, the audiation test took place in one session.

All testing sessions began with the music reading tests at the piano (approximately 30 minutes). The grand piano (Yamaha Disklavier) was equipped with Musical Instrument Digital Interface (MIDI). Videorecording was used along with MIDI to ensure the notes played were properly captured. For the sight-reading portion of the test, we administered a set of progressively challenging pieces composed by Mary Gardiner (Lemay, 2008). Participants' sight-reading cut-offs were determined by the number of mistakes made within each measure. For example, if a participant made multiple mistakes in several measures of a piece, thus disrupting the melody and rhythm of the piece (approaching non-recognition), that would be the final exercise. Following the music reading activities, participants were invited to sit at a table for the remainder of the session. Participants were provided a booklet to write in their responses for the writing tests (copying and dictation). In the case of Gordon's Measures of Music Audiation, responses were logged by the computer program.

Results

Research Question 1

Following a calculation of mean score for music reading, music writing, and audiation tests, we present the results separated by music playing level (see tables 3 and 4).

Table 3

Test Summary Mean Scores

	Music Reading (Lab)			**Music Writing**			**Audiation**		
Group	**1-note**	**2-notes**	**3-notes**	**1-note**	**2-notes**	**3-notes**	**Tonal PR**	**Rhythm PR**	**Comp. PR**
Beginner	.80	.77	.75	.89	.87	.89	71.79	57.21	62.17
Intermediate-Advanced	.84	.83	.83	.91	.91	.91	66.12	52.88	57.06

Notes: There were 13 participants in the beginner group and 11 participants in the intermediate-advanced group. 'PR' refers to 'Percentile Rank' (calculated from normative data for school grade). 'Comp.' refers to 'Composite' which is an overall score.

Table 4

Music Sight-Reading Mean Scores

Group	P1	P2	P3	P4	P5	P6	P7	P8
Beginner	10.61 (*n* = 13)	14.27 (*n* = 11)	31.57 (*n* = 7)					
Intermediate-Advanced	4.45 (*n* = 11)	6.09 (*n* = 11)	13.27 (*n* = 11)	17.81 (*n* = 11)	22.50 (*n* = 10)	16.42 (*n* = 7)	43.87 (*n* = 6)	18 (*n* = 1)

Note: There were 13 participants in the beginner group and 11 participants in the intermediate-advanced group.

Research Question 2

To compare music reading to music writing test performance, we paired subtests according to 1-, 2-, and 3-notes stimuli. All music reading and writing tests were designed with the same stimuli, but in differing orders. The testing pairs are shown in table 5.

Table 5

Music Reading to Writing Test Pairing

1-note	2-notes	3-notes
Music reading • 1-note, identification, treble clef	Mean of: • 2-notes, playing, C position, broken • 2-notes, playing, C position, solid	• 3-notes, playing, C position, broken
Music writing Mean of: • 1-note, copying, treble clef	• 2-notes, dictation, treble clef	• 3-notes, copying, treble clef

- 1-note, dictation, treble clef

Determining the distribution of the music reading and writing tests was important for the selection of an appropriate statistical method. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed and showed that the distribution of each variable departed significantly from normality ($p \leq 0.05$). Based on this outcome, the non-parametric sign test was used, and the median with the interquartile range were used to summarise each test. The results are presented in table 6.

Table 6

Tests of Normality for Music Reading and Music Writing

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Music reading: 1-note Treble Clef ID	.210	24	.008	.800	24	<.001
Music reading: 2-notes playing	.175	24	.054	.848	24	.002
Music reading: 3-notes playing	.212	24	.007	.782	24	<.001
Music writing: 1-note copying & dictation	.267	24	<.001	.677	24	<.001
Music writing: 2-note dictation	.339	24	<.001	.644	24	<.001
Music writing: 3-notes copying	.248	24	<.001	.764	24	<.001

a. Lilliefors Significance Correction

Exact sign tests were conducted to determine the effect of music reading or writing condition on 1-note, 2-notes, and 3-notes music test performance. While music reading conditions required participants to sit at a piano and either verbally name notes or play them on the instrument, music writing conditions required written responses to visual or verbal stimuli. Twenty-four participants each performed music reading tests at a piano and music writing tests at a table. While the stimuli were the same in the music reading and writing tests, the order in which they were presented differed. The scores were recorded by both Musical Instrument Digital Interface (MIDI) and manual input from videorecording for the music reading tests, and by manual input based on response booklets for the music writing tests. Table 7 outlines the test results for each pairing.

Table 7

Sign Test Results for Each Pairing

Condition	**Music reading**	**Music writing**	***Median* difference**	***p***
	Median	***Median***		
1-note	.892	.892	.000	.648
2-notes	.841	1.000	-.708	.008
3-notes	.833	.960	-.751	.011

Of the 24 participants in the study, the music writing tests elicited a more accurate performance in each note condition. For the 1-note condition, music writing brought out a more accurate performance in 11 participants compared to music reading, whereas eight participants performed better on music reading, and five participants saw no difference. There was no statistically significant median increase in test performance (*Mdn* = .000) when participants performed on the music writing condition (*Mdn* = .892) compared to the music reading condition (.892), *p* = .648. For the 2-notes condition, music writing evinced a more accurate performance in 15 participants compared to music reading, whereas three participants showed superior music reading performance, and six participants did not demonstrate a difference. There was a statistically significant median increase in test performance (*Mdn* = -.708) when participants performed on the music writing condition (*Mdn* = 1.000) compared to the music reading condition (*Mdn* = .841), $p = .008$. For the 3-notes condition, music writing revealed a more accurate performance in 18 participants compared to music reading, whereas five participants were more successful on the music reading condition, and one participant saw no difference. There was a statistically significant median increase in test performance (*Mdn* = -.751) when participants performed on the music writing condition (*Mdn* = .960) compared to the music reading condition (*Mdn* = .833), $p = .011$. In two out of three conditions, there was a statistically significant difference between the median of the differences between the two related groups ($p < .05$). Therefore, we can tentatively reject the null hypothesis and can accept the alternative hypothesis that laboratory developed music reading and writing test performances are not the same.

To calculate sight-reading proficiency, we sorted participants' cut off pieces from lowest to highest (piece 1 through piece 8). Given the uneven number of participants per each cut off piece, we designated pieces 1-3 as the low group ($n = 11$) and 4-8 as the high group ($n = 13$). Among our participants, two completed the primary level (kindergarten through grade 2), nine completed the intermediate level (grades 3 through 6) and 13 completed the advanced level (grades 7 and up). Given the level variance, we focused our analysis on percentile ranks only.

We followed the same procedure for the music reading and auditory skills test comparison by first determining the distribution to select a statistical test. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed and showed that the distribution of each variable departed significantly from normality ($p \leq 0.05$). Based on this outcome, the non-parametric

Mann-Whitney U test was used, and the median with the interquartile range were used to summarise each test. The results are presented in table 8.

Table 8

Tests of Normality for Audiation

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Gordon Composite Percentile rank	.163	24	.100	.899	24	.021
Gordon Tonal Percentile rank	.165	24	.090	.897	24	.018
Gordon Rhythm Percentile rank	.168	24	.078	.901	24	.023

a. Lilliefors Significance Correction

Following the Mann-Whitney U test for each parameter, we visually inspected each median distribution[13]. The next step following the Mann-Whitney U test was to correct for Family Wise Errors (reducing type I error) with a Holm-Bonferroni correction (Holm, 1979). Both *p* values and α values are shown in table 9.

Table 9

Values of the Gordon Tests

Test	**Rank**	**Original *p* value**	**Corrected α value**
Tonal PR	3	.705	.016
Composite PR	2	.283	.025
Rhythm PR	1	.223	.050

Note: Corrected α values were compared to the original *p* values to determine whether to reject the null hypothesis. Our conclusions can be expressed in this manner. Regarding the Tonal PR,

[13] Refer to the Appendices for the visual representation of the medium distributions in population frequency pyramids.

distributions of scores for low and high cut-off participants were not similar, as assessed by visual inspection. There was no significant difference in performance between low and high cut-off groups, $U = 65$, $p = .016$. For the Composite PR, distributions of scores for low and high cut-off participants were not similar, as assessed by visual inspection. There was no significant difference in performance between low and high cut-off groups, $U = 53$, $p = .025$. Finally, for the Rhythm PR, distributions of scores for low and high cut-off participants were the most alike compared to the other two measures, as assessed by visual inspection. There was no difference in performance between low and high cut-off groups, $U = 50.5$, $p = .05$. In all three conditions, Composite PR,Tonal PR, and Rhythm PR, there was no significant difference in performance between low and high cut-off groups, ($p > .05$) suggesting we accept the null hypothesis that performance for low and high-proficiency sight-readers are the same.

Discussion

As expected, the mean results of the music reading and music writing tests were influenced by musical experience. The more advanced group (level 2) performed more accurately compared to the beginner group (level 1). We expected to see higher audiation scores in the more advanced group compared to the beginner group, but the results do not reflet this. This is likely due to the type of audiation test administered to the participants in the more advanced group. *Gordon's Measures of Music Audiation* (Gordon, 2001) is a test dependent on school grade, with a breakdown of primary (kindergarten through grade 2), intermediate (grade three though six) and advanced (grade seven and above). In the progression from primary through advanced versions of the auditory test, the stimuli pairs become more challenging. In our beginner group, the distribution was primary ($n = 2$), intermediate ($n = 8$), and advanced ($n = 3$). Comparatively, our more advanced group had a distribution of intermediate ($n = 2$) and advanced

($n = 9$). Regarding music sight-reading, we did not have any expectations due to the variety of musical backgrounds of our participant group. It is logical that the beginner group (level) reached piece 3, because it was the first piece requiring both hands to play simultaneously. In the more advanced group, the discrepancy between the lower (better) score on piece six compared to piece five could be explained by the fewer number of participants who attempted the more challenging piece, four of whom were playing repertoire at Royal Conservatory of Music grade eight and above, thus they were advanced players. In comparison, the others in their intermediate-advanced group were playing repertoire at about a Royal Conservatory of Music grade five level.

We performed a paired sign test on three conditions pertaining to music reading and writing, comprising 1-note, 2-notes, and 3-notes. While we tentatively rejected the null hypothesis and accepted the alternative hypothesis, we can discuss how the demands on each test support the results of each condition pairing. In the 1-note condition, the demands for both music reading and writing conditions were few. In the music reading test, participants viewed notes that briefly appeared on a computer screen, in treble clef presentation. Participants named notes aloud (14 used letters, nine used solfege, and one used both naming systems) while the administrator recorded responses. Apart from correctly naming notes, the biggest challenge was the duration of stimuli on screen (one second) resulting in 49 non-responses. In reading research, difficulties with rapid response to alphanumeric symbols are often linked to slow word decoding, but this is often impacted by the age at which children start learning to read (Peterson et al., 2013). The music writing counterpart comprised both 1-note copying and dictation exercises. There was no time limit for each task, but participants were instructed to write as quickly as possible. The copying task was administered consistently before the dictation task, to allow for familiarity in how the stimuli looked on the computer screen, to be inclusive to participants with little writing experience. Despite having the copying test stimuli as reference, several participants repeatedly drew the notes with stems too long, too short, or improperly oriented. This is in accordance with several author groups of writing and spelling, which have indicated that graphomotor automatisation (typically measured by speed writing alphabet letters) continues to have variance throughout childhood and even into adulthood, in time-constrained situations (Berninger et al., 1991; Graham et al., 1997; Jones & Christensen, 1999; Medwell, Strand, & Way, 2007; Pontart et al., 2013).

In the 2-notes and 3-notes conditions, the demands required for the music reading tests were greater than those for the writing, and this is reflected in the statistically significant median increases in writing performance. For the music reading conditions, participants decoded stimuli groups of two and three notes in C position on the treble clef, within a five-finger hand position. Decisions included determining pitches, intervals, appropriate fingers, note directions, and manner of playing (either blocked notes played simultaneously, or broken notes played consecutively) while the stimuli remained on screen for two seconds. In short, the decoding tasks required perceptual, cognitive, and motor demands within a short time constraint (Kopiez & Lee, 2008; Rosemann, Altenmüller, & Fahle, 2015). Comparatively, the music writing conditions for 2-notes (dictation only) and 3-notes (copying only) had positive median differences for 62.5 % and 75% of participants, respectively. In writing research, children both with and without dyslexia diagnosis demonstrate ability to self-correct copied text, however it is in dictation tasks where children with dyslexia struggle more, without being able to make the phonological connection between sound and symbol (Re & Cornoldi, 2015). Given that no participants had a dyslexia diagnosis, it is not surprising that dictation performance was superior to decoding performance. However, we did find evidence of self-correction in 14 participants in the copying task, and in six participants in the dictation task, suggesting that participants were more aware of their mistakes with a visual reference point. We could consider our findings as support for the claim that measuring dysmusia has to account for domain specificity. The challenges described above for music reading are not comparable to text reading and we should not assume that music reading and writing abilities interact identically to text reading and writing.

We performed a Mann-Whitney U test on two independent sample groups of participants (low and high sight-reading proficiency) who completed Gordon's *Measures of Music Audiation* (Gordon, 2001) an audiation test. Through the test program, participants' scores were assigned a percentile rank (PR) for tonal audiation, rhythm audiation, and composite (overall) audiation. For all parameters, we found that median performances between groups were about the same, equal, thus we accepted the null hypothesis. However, based on visual inspection, the results showed some slight differences between low and high proficiency sight-reading groups.

For the tonal PR, there was variance in population frequency distribution. Within the low sight-reading proficiency group, percentile ranks ranged from 25 to 100, and were most concentrated between 50 and 80 (average to high). However, in the high-sight-reading proficiency group, percentile ranks ranged from 50 to 100, and were most concentrated between 80 and 100 (high). When comparing the two groups of participants, the low-sight reading group had on average four years of music lessons compared to the high-sight-reading group, which comparatively had 6.5 years. Author groups suggest that prolonged musical training shapes sound sensitivity at the cortical level, meaning musicians with more musical experience will have enhanced capacity for auditory tests compared to less trained counterparts (Baeck, 2002; Hyde et al., 2009; Schlaug et al., 2009). For example, in Hyde and colleagues' (2009) study, 30 children were given either 15 months of private instrumental music lessons or no private lessons, about 15 per group. After 15 weeks, the instrumental group demonstrated greater improvement on both melody and rhythm discrimination tasks compared to the controls, and this was reflected also in the brain scans.

For the rhythm PR, visual assessment of population frequency reveals less concentrated scores compared to the tonal PR. For example, the low sight-reading group ranged from >1 to 100, compared to 20-100 for the high-sight-reading group. This wide range suggests two possibilities dependent on a larger sample size. First, music sight-reading proficiency is not likely a predictor of rhythm audiation performance among our participant sample without dyslexia. Second, this result contrasts with the literature on music training enhancing auditory sensitivity. A possible explanation is that there is an effect of type of musical training. In the study by Hyde and colleagues (2009) all the participants received the same musical training, whereas in our study, the type of training varied from exclusively music reading based approaches (e.g., through method books), to hybrid ear-based and music reading approaches (e.g., Suzuki Piano paired with Royal Conservatory of Music). Moreover, we caution that the group similarities we found on rhythm PR for our population without dyslexia may not be true for cases of dysmusia or dyslexia. In dyslexia literature, rhythm training is often used as a remedial tool for children with dyslexia, to improve their text reading fluency (Bonacina et al., 2015; Leong & Goswami, 2014; Overy, Nicolson, Fawectt, & Clarke, 2003; Przybylski et al., 2013). Therefore, we suggest administrating the same test to children suspected of having dysmusia and compare results to controls matched for age.

Conclusion

In conclusion, our exploration of music reading, music writing, and audiation tests in young piano students created the beginning of a baseline to which we can expand, and against which we can compare to suspected cases of dysmusia. With a participant sample without dysmusia or a diagnosis of dyslexia, we obtained mean scores for both beginner and intermediate-advanced players because experience is likely a factor in test performance. Due to links between reading and writing, and reading and auditory skills in language literature, we explored these relationships with our music tests. Regarding music reading and writing, the data showed that while single note naming and single note writing (both copying and dictation) are similarly difficult, music decoding is significantly more challenging compared to music writing on both two- and three-note conditions. While this differs from text reading literature in which both skills are comparably difficult, we can expect that future cohorts of piano students without dysmusia will continue to make more decoding than writing mistakes, and this gap will likely be wider in cases of dysmusia. Regarding music sight-reading and audiation, the data showed that there is no statistically significant difference between groups, but visually there appears to be aa tendency for more proficient sight-readers to have better overall and tonal audiation compared to less proficient sight-readers. However, this is not the case of rhythm audiation, which was visually close to equal in difficulty based on visual inspection, despite being statistically insignificant. We posit that the variability of participant backgrounds can account for diverse experiences and familiarity with rhythm audiation training. Given that rhythm training is often used as a remedial took in cases of dyslexia, it could be especially beneficial to compare test results with age- and level-matched cases with suspected dysmusia to test if deficiencies are present.

Limitations

With dysmusia being a new avenue of research within which there has been limited quantitative testing, and no testing with young piano students, the structure of the study was formed based on existing research paired with researcher discretion. However, using informed discretion led to freedom for method, participant, and analysis selection. A small sample size of 24 participants varying in age and musical experience reduced the number of options for statistical testing and increased the risk of non-representative test performance. Even so, our focus was on the tests themselves rather than the participants themselves, and we ran normality tests to account for variance at the analysis stage. Non-normally distributed data predicated the selection of non-parametric tests with lower statistical power. Nevertheless, the results can be used to inform how future studies exploring music reading, music writing, and audiation among young pianists, especially as novel screening tools often undergo multiple phases of testing.

Implications for further research

There are several avenues future research. Using a case study approach, researchers could explore how young pianists with a dyslexia diagnosis and suspected dysmusia perform on the same selection of tests and compare them to age-matched and level-matched peers. In this way, the unique characteristics of the cases could situate the cases' test performance within the environment in which they are learning music both at home and at the music lesson. To continue building on the tests explored in this study, researchers could aspire to replicate the results found with several more populations of children without dyslexia or suspected dysmusia, to continue to refine the proposed screening tool baseline. Finally, with the existence of more quantitative data in non-dyslexic and non-dysmusic controls, researchers can recruit samples of children with diagnoses of dyslexia as well as with documented difficulties with music reading to which test performance can be compared.

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Chapter 5: Dysmusia in Childhood: A Case Study of a Candidate

Abstract

We document the case of a candidate for dysmusia in childhood. Eloise Armstrong (EA) is a 10-year-old girl with dyslexia enrolled in piano lessons. We interviewed EA along with her mother, Rosalyn Armstrong (RA), and communicated via e-mail with her piano teacher to develop a case description. The purpose of the study was to explore if EA likely has dysmusia based on test performance, considering her environment as a factor in her performance. Looking at the interviews through a holistic content approach, we identified two salient themes, family involvement and positive attitude towards learning, and described them with evidence from the transcripts. We compared our case's test performance data for music reading, music writing, and audiation skills to age-matched and music playing level matched controls, as well as processing speed and motor dexterity performance to standardized scores. The results show that EA does not likely have dysmusia based on music test performances that are close to the control group. Slight differences in EA's performances include a lower score in note identification, decoding notes when the presentation included solid as well as broken notes. EA made more rhythm errors in sight-reading compared to controls, though pitch errors were comparable. Audiation scores were slightly varied from the control group with a slightly lower tonal and slightly higher rhythm percentile rank. We discuss how EA's performances likely disqualify her from having dysmusia and discuss how dysmusia could either appear when a musician with dyslexia attains a more advanced level of study or be a domain specific condition. Both avenues of dysmusia exploration should be studied further.

Keywords: Dysmusia, Music, Dyslexia, Piano, Children, Case

Background

Dysmusia, or difficulties in music reading, is often discussed with respect to musicians with dyslexia. We take the position that the two are related, as several musicians with dyslexia report difficulties in music reading as well in other parts of their musical learning and performance, as well as teachers observing difficulties experienced by their students, particularly music writing and audiation (Authors, 2022a). As we have explored music reading, music writing, and audiation tests suitable for creating baseline data in a control group of participants, we have yet to compare our results to a case participant with dyslexia and suspected dysmusia (Authors, 2022b, Authors, 2022c). Furthermore, we have not compared the data of a dysmusia candidate to standardized scores for processing speed and motor skills, which are often deficits associated with dyslexia according to the British Dyslexia Association (BDA). While it is imperative in the development of a screening tool for dysmusia to explore test feasibility with several students suspected of having dysmusia, an intermediate step is to explore a singular case, because that can provide an understanding of how dysmusia may or may not have an impact on the individual level.

Existing Case Studies in the Literature

While qualitative (Ashcroft, 2019; Du Toit, 2013; Ganschow, Lloyd-Jones, & Miles, 1994; Nelson, 2014; Vladikovic, 2013), and pedagogical cases (Miles et al., 2001; 2008; Oglethorpe, 2002) of musicians with dyslexia exist, there is only case study with empirical components about a musician with dyslexia who potentially has dysmusia (Hébert et al., 2008) and only one qualitative study on young piano students with a diagnosis of dyslexia (Vladikovic, 2013).

Hébert and colleagues (2008) used the BRAMS Music-Reading test to conduct a case study of a university music student with dyslexia who was suspected of having dysmusia. The researchers compared the student, IG, to previously acquired group data on the same battery. In short, the battery includes visual input tasks (pitch reading, rhythm reading, symbol identification, symbol discrimination skills, and visual recognition of familiar tunes) and auditory input tasks (repetition and recognition). It should be noted that the visual input tasks require singing rather than playing on an instrument. Regarding visual presentation, IG scored below and differently than the normal readers on all tests, particularly in her pattern of performance in the pitch and rhythm reading tasks. IG struggled with reading pitch and rhythm stimuli but demonstrated good repetition of pitch and rhythm stimuli. Conversely, the normal readers demonstrated better reading of pitch and rhythm compared to repetition of pitch and rhythm. IG's recognition of visual familiar tunes was poorer and slower compared to the normal readers; however, when the input was auditory, her reaction time and accuracy paralleled the normal readers. On the discrimination tests, IG performed more poorly than the normal readers, but the same pattern emerged; as the stimuli increased in difficulty, her scores decreased. In the case description of IG, the authors provided information about the several musical instruments she played, as well as the vocal and instrumental ensembles in which she had taken part, all of which contributing to success at entering her undergraduate program in vocal performance.

Vladikovic (2013) explored the concept of musical giftedness among piano students with dyslexia. She surveyed piano teachers about their experiences teaching children with dyslexia. Then, she presented the case of teaching her seven-year-old student, John, who struggled with music reading despite his high motivation and enthusiasm for piano:

> John displayed difficulties in sight reading, hand coordination, finding the right octave on the keyboard, and mixing up notes between lines and spaces, which soon led me to suspect

> the possibility of dyslexia… John would often reverse notes with and without accidentals. The music might have an accidental in one hand, but he would persist in playing the accidental in the other hand, even if the "wrong" hand was not in a natural position for it. … Another difficulty was that John would play a much larger interval than written, especially when one of the notes was marked with a sharp (pp. 47-48).

Despite these challenges in music reading, after six years of instruction, John was preparing his level eight examination with the Royal Conservatory of Music (Toronto) suggesting that in this case, music reading challenges did not lead him to abandon piano study. Vladikovic provided details about John's encouraging family and peers, commitment to piano practice, and desire to overcome challenges, all of which contribute to his musical success.

Research Problem

To date, we have baseline data in a group of young piano students without dysmusia or dyslexia for tests of music reading, music writing, and audiation, to which we can compare case data. Additionally, we can compare case data to age-based percentile ranks on standardized processing speed and motor tests, which are also common deficits shared by dyslexia and dysmusia. Existing case studies on the topic of music and dyslexia are framed by the context in which the cases are learning music, but no case studies with children have an empirical component. Exploring a specific case in detail will contribute to our understanding of how dysmusia could look in childhood, considering both test scores as well as home environment and approaches to learning Our research questions are:

1. Which aspects of a young pianist's home environment and approach to learning might influence her test scores?
2. Does a young pianist likely have dysmusia based on her test performance?

Method[14]

Case Selection

A young pianist with dyslexia was referred to the authors by her parents due to her initial difficulties with music reading at age three, which were later thought to be related to her diagnosis of dyslexia, which occurred years later.

Case Description

Eloise Armstrong[15] is a ten-year-old piano student, born and raised in a large metropolitan city in western Canada. Her parents, Rosalyn and James, who are musical but work in veterinary medicine and the trades respectively, encourage Eloise and her two siblings Tyler and Nicole to participate in music lessons. At about age three, Eloise began group classes with the Music for Young Children Sunshine program[16] (https://www.myc.com/) and Rosalyn noticed learning difficulties. Compared to her older brother, Tyler, who internalized the concepts immediately, Eloise struggled with processing and retaining information from day to day, requiring a lot of repetition. This difficulty manifested in music reading, with learning the notes on the staff. However, other activities in the group lessons, such as rhythm exercises, were not as difficult for Eloise. Shortly thereafter, Eloise began kindergarten at a bilingual English-Spanish school, and similar difficulties appeared when learning to read text. For example, when learning

[14] Refer to Chapter 8: Appendices, for materials discussed in this chapter.

[15] All names are pseudonyms.

[16] Musical goals in the Sunshine 1 course include: mastering musical alphabet from A to G both in recognition and playing on the piano in C major and A natural minor scales; recognizing high, low, and medium sounds, recognizing and playing patterns by ear on the piano; reading notes on the lines and spaces from middle C through E and bass clef A and B; be able to read pre-staff notation hands separately; echo sing patterns; use 2/4, 3/4, and 4/4 time signatures; employ whole, half, quarter, and eighth notes in singing, clapping, dictation, and reading.

rhyming words, Eloise needed to sound out each one, despite being told they had the same vowel sounds. By the time Eloise reached grade two, her schoolteacher recognised Eloise being a year behind in reading compared to her peers, and a psychoeducational assessment led to diagnoses of dyslexia, dyscalculia, and dysgraphia. With regularly scheduled speech-language therapy and mathematics tutoring, Eloise has continued to improve at school. According to her most recent report card, Eloise demonstrates well-developed understanding in most aspects of all school subjects and has an Individualized Education Plan (IEP) for the aspects of mathematics and languages in which she struggles. Rosalyn notes persistent difficulties in writing: poor spelling, varied letter sizes, and lack of punctuation and capital letters. In her musical training, Eloise transitioned to the Piano Safari method at about age six, which emphasises learning music notation with an intervallic approach (https://pianosafari.com/). Shortly thereafter, Eloise switched piano teachers and began the Conservatory Canada program at age eight (https://conservatorycanada.ca/). She passed her grade two practical exam in 2021 with first class honours and is now pursuing grade three.[17] Eloise enjoys her piano lessons and learning new music. She reported preferring to learn music by reading the score, followed later by memorisation. Through email correspondence, Eloise's current piano teacher, Miss Larissa, describes Eloise as one of her strongest students, and indicated surprise when she learned about Eloise's diagnosis from the parents. Compared to other students with known diagnoses of dyslexia, Eloise is an average music reader, and does not demonstrate what Larissa has seen often: difficulties with sight-reading and hand coordination. Rosalyn noticed that Eloise relies on the score much more than her older brother, who prefers to learn by ear. Currently, Rosalyn is

[17] Eloise's piano examination was conducted via Zoom. The sight-reading portion of the examination was completed in real-time (no advanced preparation).

unaware of any persistent music reading difficulties experienced by Eloise beyond occasional confusion with accidentals and key signatures, and perhaps taking more time to learn repertoire compared to her brother. Eloise maintains a practice schedule of about 30-minute sessions five to six times per week and has access to a quiet room with a baby grand piano, where practice is mostly uninterrupted, with occasional visits from Rosalyn or younger sister, Nicole. Rosalyn mentioned that Eloise wears glasses for near vision tasks for school, but rarely wears her glasses during piano lessons and practice.

Design

We selected a mixed methods design for the purposes of complementarity, which "deploy different methods in order to develop a broader understanding of the research problem" (Gibson, 2015, p. 388). The complementary approach focuses on the strengths of each method and the result will be a deeper understanding of EA's case of potential dysmusia rather than trying to achieve an absolute truth of what dysmusia could be in all cases. The two methods used in this study are narrative analysis (Lieblich, Tuval-Mashiach, & Zilber, 1998; Smith & Sparkes, 2008) and case control, where the case's performance is matched to peers for their similar values (McKnight, 2017). For the purposes of this study, we considered the pairings based on context. To compare our case's processing speed and motor skills, we simply used the available standardized data for the *Comprehensive Trail Making Test, 2nd edition* (Reynolds, 2019), and the *Purdue Pegboard Test* (Lafayette Instruments). Considering music reading and writing, it is best to compare our case to peers with similar musical playing expertise. As our case is playing at a Conservatory Canada grade 3 level, we selected the entire beginner group from our previous study (*n* = 13). Specific to sight-reading, we narrowed the controls to those who reached the same cut-off piece as the case (*n* = 6), as well as to one specific child with relatively similar years in lessons and musical achievement. Regarding the audiation test, both age and experience were interesting variables to explore. The audiation test, Gordon's *Measures of Music Audiation* (Gordon, 2001), is age dependent in its calculation of percentile ranks, thus we created a control group of 10-year-old participants (*n* = 5). However, we consider previous research that expertise may influence audiation performance, and our 10-year-old group contains a mixture of beginner and intermediate pianists. Therefore, we chose to include the beginner group as well (*n* = 13).

Materials

The tests administered comprised both non-standardized and standardized tests. The music reading and writing tests, while non-standardized, address note identification, note decoding, music copying, and music dictation with the same stimuli. Separate from the laboratory developed music reading tests, we included a sight-reading test series by composer Mary Gardiner, wherein pieces become progressively challenging. Gordon's *Measures of Music Audiation* (Gordon, 2001) is a standardized test run on a computer. The program is divided into two subtests—tonal and rhythm—where the participant indicates whether pairs of either short melodies or beat patterns are the same or different. Finally, we included *The Comprehensive Trail Making Test, 2nd edition* (Reynolds, 2019) which is a measure of two types of processing speed: inhibitory control [18]and set shifting[19] and the *Purdue Pegboard Test* (Layfette Instruments) which is a measure of dexterity.

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[18] "Inhibitory control of attention (interference control at the level of perception) enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli" (Diamond, 2013, p. 137).

[19] "Cognitive flexibility (set shifting): changing perspectives or approaches to a problem, flexibly adjusting to new demands, rules, or priorities (as in switching between tasks)" (Diamond, 2013, p. 137).

Procedure

Upon receiving ethical approval, the case study participant, EA, and her mother, RA, completed consent forms to participate in the research project. The principal investigator met with EA and RA via videoconferencing for separate interview sessions, lasting approximately 40 minutes each. The sessions were recorded such that the principal investigator could transcribe the audio to text. Following interview transcription, the principal investigator analyzed the interviews according to a holistic content approach, with emerging themes intended to support the case's description. The principal investigator achieved rigour through a discussion with a peer reader about theme selection, mitigating personal biases. After the story and themes were written, the principal investigator sent the results to the case and her parent for approval. On a separate occasion, the research assistant travelled to the case's home to administer the tests. In a quiet room with a baby grand piano, the research assistant video recorded the music reading and sight-reading tests, lasting approximately 30 minutes. At the beginning of the test session, the research assistant provided the case with the option of either wearing or not wearing her glasses according to her comfort level. After the first practice trial, the research assistant asked the question a second time, and the participant decided to wear her glasses. Following the music reading tests, the participant completed the writing, audiation, trail making, and pegboard tests at a table. Responses were tracked on a log sheet by the research assistant.

Results & Analysis

Research Question 1: Eloise Armstrong: Global Impression and Themes

Eloise is an enthusiastic, clever, and kind 10-year-old girl, surrounded by a nurturing family and occupied by several extra-curricular activities depending on the season, including dance, swimming, cross-country skiing, and hiking. In discussion with Eloise, she never mentions her diagnosis of dyslexia. Her mother, Rosalyn, explains that the familial attitude towards Eloise’s dyslexia is that of a learning difference: “I just try to be more with her, like, ‘You have a learning difference.’ I just tell her that she learns differently.” Piano lessons are one of several ways that Eloise enjoys music in her daily life. Eloise states four times that she enjoys playing songs [on the piano], as well as singing songs in English and Spanish using her karaoke machine, playing piano duets with her grandmother, listening to music every Sunday with her family, participating in studio recitals and Christmas concerts, and attending the symphony. In all her life stages from early childhood, and first music lessons through present day, two salient themes consistently appeared: family involvement, and positive attitude towards learning.

Family Involvement

Eloise started learning the piano at age three, citing that her mom wanted her to try it out to see if she liked it. Rosalyn explained that her own mother, as a piano teacher, taught her piano, and it was a positive experience. She reflected, “Who ever regrets having to take piano lessons?” and affirmed that she wants her children to also benefit from their lessons, too. Rosalyn accompanied Eloise to her Music for Young Children group classes, and it is through her involvement that she noticed Eloise’s struggles with learning musical notation. At home, they worked on the homework together, until Eloise began private piano lessons around age eight. Rosalyn’s involvement presently continues with semi-regular communication with Eloise’s piano teacher, Miss Larissa. Both Rosalyn and her husband, James, accompany Eloise to her piano recitals and cheer her on. To support Eloise’s interest in music and singing, they recently gifted her a karaoke machine, which she uses often. Eloise indicated a preference for singing songs in both English and Spanish. From time to time, Eloise will sing to music along with her younger sister, Nicole. Music plays a role in Eloise’s relationship with her family in general.

Eloise talked about a tradition of listening to music every Sunday over breakfast. When this tradition was discussed with Rosalyn, she appeared touched, expressing, “Ah, no kidding, so she notices that?” Rosalyn described that this tradition dates to her own childhood with her two brothers. Her older brother, Henry, selects the playlist, an eclectic mix of folk, indie, and classical. Meanwhile, her younger brother, Christopher, who lives in another city, contributes to the family music traditions by gifting tickets to the symphony orchestra.

Positive Attitude Towards Learning

When asked about her music lessons, there was very little that Eloise did not enjoy. Apart from referring to practicing scales as “boring”, she reported that the rest of her lesson experience was positive. Learning new music was cited as the most enjoyable. When presented with the challenge of playing at a recital and forgetting the notes, Eloise recalled stopping, finding her place, and continuing. While she admitted to feeling butterflies prior to and during the performance, she looks forward to the next recitals. Her parents were impressed by how Eloise reacted to the stumble. James recalled that Eloise handled the situation through calming herself down and taking deep breaths. Upon reflecting about school subjects, Eloise described in detail her fascination of the scientific method, memorizing grammar rules in Spanish, and understanding world history. Rosalyn emphasizes Eloise’s positive attitude towards learning on two separate occasions. On the first occasion, Rosalyn describes Eloise’s dedication to overcoming challenges in mathematics:

> She has a really great attitude about things. She’s in math tutoring and stuff, and even the math tutors have said, ‘She’s got an amazing attitude.’ She tries. You get kids who go to a tutoring place and they’re like, ‘I don’t want to be here, I don’t need to be here.’ But, she tries. She hates missing school. She’s always willing to do something.

On the second occasion, Rosalyn confirms that this is Eloise’s general temperament both at home and school.

Research Question 2: Test Performance

EA's performances on the trail making and pegboard tests are presented with reference to normative data. EA's performances on music reading and writing, music sight-reading, and audiation tests are presented, with comparisons to controls matched for age and music playing level depending on the requirements of the test.

Trail making. EA completed all five trails comprising the *Comprehensive Trail Making Test, 2nd edition* (CTMT-2) (Reynolds, 2019). At the time of testing, EA was 10 years and seven months old, and as such her score was calculated based on age norms for children between 10 years and six months and 10 years and 11 months old.

Table 1

EA's CTMT-2 Performance

			Indexes		
Trail	**Time (s)**	**PR**	**ICI PR**	**SSI PR**	**TCI PR**
1	58	1	1	2	1
2	84	2			
3	124	<1			
4	87	2			
5	123	4			

Notes: PR refers to 'Percentile Rank.' ICI refers to 'Inhibitory Control Index', SSI refers to 'Set-Shifting Index', and TCI refers to 'Total Composite Index.'

Trails one through three comprise the Inhibitory Control Index (ICI), a type of processing speed which requires the participant to selectively attend to certain features while ignoring others. In trails one through three, EA connected Arabic numerals 1 through 25 that appeared in circles, selectively attending to them and ignoring any circles with no numbers, and any circles with distracting symbols. Her Percentile Rank (PR), 1, is described in the CTMT-2 manual as severely impaired. Trails four and five comprise the Set-Shifting Index (SSI), a type of processing speed which requires the participant to flexibly adjust to new rules. In trail four, EA connected Arabic numerals in circles to Arabic numerals written in letter form in rectangles. In trail five, EA connected Arabic numerals in circles to letters of the English alphabet in circles. Her PR, 2, is also described as severely impaired. Combined, the Total Composite Index (TCI) comprises all five trails, and EA's PR of 1 reflects both aspects of processing speed.

Pegboard. EA completed the Purdue Pegboard Test (Lafayette Instruments) subtest that requires the participant to place pins in parallel rows of 25 holes (one column per hand) on the pegboard with a timeframe of 30 seconds. In accordance with the procedure used by Gardner and Broman (1979), EA completed one trial. EA placed 12 rows of pins. Normative data for EA's sex (female) and age group (10 years, 7 months) places her PR at 19 (Gardner & Broman, 1979, Lafayette Instruments).

Music reading and writing 1, 2, and 3 note conditions. EA completed music reading and writing tests that were designed with the same stimuli. All conditions were paired by the number of notes required. All notes were presented in the treble clef, and all music playing conditions, with two and three notes, respectively, were on a five finger C position that was played with the right hand. All notes appeared as quarter notes. The 2-notes appeared in both solid (blocked) and broken presentations. The 3-notes appeared in broken presentation only. The only music reading condition that did not include playing the piano was the 1-note, where the participant is required to name notes aloud on the treble clef. The music writing conditions include both copying notes on the treble clef (1 notes and 3 notes), and dictation (1 note and 2 notes). All the copying stimuli have a broken presentation, in quarter notes. For the dictation conditions, the participant has the choice to write the notes in their preferred way, so long as they use quarter notes. See table 2 for EA's results compared to level matched controls.

Table 2

EA's Music Reading and Writing Performance on 1, 2, and 3 Note Conditions

	Percent Correct			
	EA	Playing level group average		
		***n* = 13**	***SD***	***difference***
Music reading				
1-note	.64	.79	.24	.15
2-notes	.72	.77	.24	.05
3-notes	.90	.76	.28	-.14
Music writing				
1-note	1.0	.90	.18	-.10
2-notes	1.0	.88	.25	-.12
3-notes	.98	.90	.16	-.08

On music reading conditions, EA's performance compared to the playing level controls was mixed. For the 1-note condition (naming) EA's performance was less accurate compared to the controls. Similarly, on the 2-notes condition (playing) EA's performance was less accurate than the controls (included both solid and broken presentations). However, on the 3-notes condition (broken only), EA's performance was more accurate than the controls. Unprompted, EA remarked to the research assistant that she preferred the broken notes presentation compared to solid. On music writing conditions, EA's performance was more accurate compared to the controls on all three conditions. In fact, on 1- and 2-note conditions, EA made neither notehead placement nor descriptive (spacing, stems, corrections) errors, resulting in 100% accuracy.

Sight-reading. EA completed the first three sight-reading pieces in the series. The third piece in the series requires both hands to play simultaneously, unlike the first pieces where the melody is exchanged between the hands. In the third piece we noticed several differences between EA's performance and those of a control matched for playing level and age, as well as to the control group of beginner participants. Overall scores for piece three are in table 3.

Table 3

EA's Overall Performance on Sight-Reading Piece 3

	EA	Matched Control	Beginners
			***n* = 6**
Pitch errors	13	13	22
Timing errors	14	2	8

Regarding pitch errors, EA's score was comparable to the matched control participant, but lower than the group average. This could be explained by the range in playing level of the control group, with some control participants having less playing and music reading experience. However, for timing errors, EA made considerably more compared to both the matched control and the beginner group. To investigate further, we looked at the type of errors made in the sight-reading evaluation chart (see table 4) and the marked score (see figure 1).

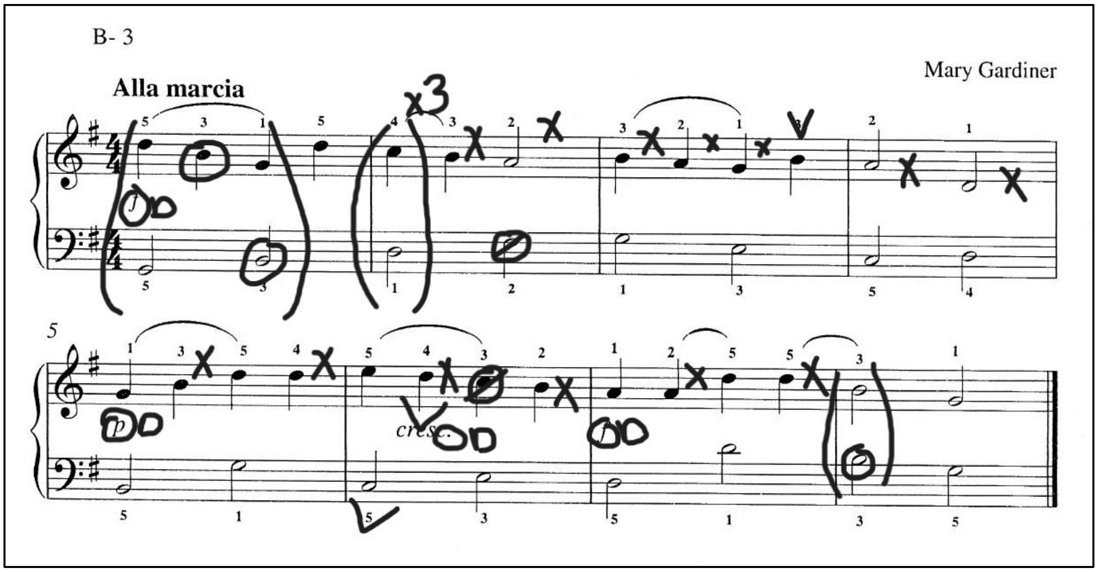
Table 4

EA's Sight-Reading Errors for Piece 3

	Pitch errors	**Timing errors**
EA	Additions: Omissions: 3 Substitutions: 2 Restriking: 5 Replaying: 3 **Total: 13**	Duration: 14 Tempo change: **Total: 14**
Matched Control	Additions: Omissions: Substitutions: 12 Restriking: 1 Replaying: **Total: 13**	Duration: 3 Tempo change: **Total: 3**

Figure 1

EA's Marked Score for Piece 3



EA’s sight-reading evaluation and marked score revealed that timing errors concerned duration, that is, several notes played did not adhere to their respective durations. From measure two onwards, EA paused after every note, or every other note, suggesting that she was not reading ahead in the music. However, the pauses taken provided ample time to decode the pitches. EA’s most frequent pitch mistakes were restriking errors (one note) and replaying errors (a group of notes). EA only substituted two, and omitted three notes, meaning that most of the pitches she played were in the correct place. Comparatively, the control participant’s pitch errors were nearly all substitutions, where most of the notes were played in the incorrect place.

Audiation. EA completed the Intermediate Measures of Music Audiation (IMMA) test (Gordon, 2001) because at the time of testing, she was in grade five at school. We compared her percentile ranks for tonal, rhythm, and composite to controls of the same age and school grade (all who completed the IMMA) and to controls of the same playing level (who completed a mixture of the primary, intermediate, and advanced tests). See table 5 for results.

Table 5

EA's Performance on IMMA Compared to Age-Matched and Level-Matched Controls

	EA	Age-matched average	Playing level group average
		***n* = 5**	***n* = 13**
Tonal PR	65	73	69
Rhythm PR	40	32	45
Composite PR	50	43	57

EA's performance on the IMMA is about average according to her percentile ranks (PRs). Compared to age-matched peers who also completed the IMMA, EA had a superior PR for rhythm and composite parameters (one range level higher), and a lower score on the tonal parameter (one range level lower). Compared to control participants who are matched for approximate playing level (beginner), EA's performance was slightly lower, though all fell within the same ranges.

Synthesis of Research Questions 1 and 2

Combined, our qualitative and quantitative data create a bigger picture of EA and her candidacy for dysmusia. EA's scores on the trail making test are in accordance with her diagnosis of dyslexia. Due to a deficit in processing speed, EA's PRs were around 1. EA's PR of 19 on the pegboard subtest points to a possible motor deficit, though dyspraxia was not determined at EA's psychoeducational assessment.

Concerning music reading, EA's scores, while lower than the controls in the 1-note condition, are still nearly 70% accurate. EA's 1-note identification score corresponds to how her mother noticed early on that learning the names of the notes on the staff was more challenging for her compared to her brother at the same age. In the 2-notes playing condition, EA's score was also lower than the controls. However, in the 3-note condition, EA's score was higher compared to the controls. In this condition, the presentation was broken, and EA reported a preference for this presentation. EA spent two years of her musical training following the Piano Safari method, which encourages pattern playing of similarly grouped broken presentation patterns. Perhaps there is an influence of instructional background. Concerning music writing, EA's high accuracy and superior performance compared to the control group contrast with her diagnosis of dysgraphia.[20] Furthermore, EA's mother described her text writing as including, "[bad] spelling, different sized writing, you know, the punctuation, lack of capitals, and all that kind of stuff." However, EA's note drawings were neat and nearly without descriptive errors. From the interviews, it was salient that Eloise enjoys the learning process, to the point of never wanting to miss her music lessons, school, or speech-language therapy sessions. When asked about her language learning process in school for Spanish class, EA enthusiastically described all the grammar rules she recently learned, suggesting an attention to detail. Her attitude towards learning likely influenced her time spent practicing her note identification and playing, and attention to detail for note drawing.

With respect to music sight-reading, EA's performance of piece 3 (the first piece of the series to be played with both hands simultaneously) had approximately the same number of errors as the control group, and had considerably more rhythm errors compared to a control matched more closely to EA's playing level and age. In the interview, EA indicated a preference for and enjoyment of learning music by reading, and her mother reported that EA relied far more on the score compared to learning music by ear. Furthermore, her sight-reading specific to the piano passage on her 2021 piano exam was 5.3/7 (approximately 76%) and the rhythm sight-

[20] 'Dysgraphia refers to a learning disorder related to difficulties with handwriting 'such as forming letters or words or writing within a defined space' (Farrell, 2021, p. 81).

reading score was 3/3. EA's current piano teacher, Miss Larissa, confirmed that rhythm in the context of music reading was not a point of difficulty for her. Perhaps the discrepancy between EA's rhythm errors on our sight-reading test, and her excellent rhythm skills according to her last piano exam as well as her piano teacher could be explained by preparation time. In our sight-reading exercise, EA was instructed to begin playing as soon as she placed her hands on the piano, with no preparation time. Typically, piano examinations permit candidates to silently prepare the music for a short time.

For audiation, EA's performance was comparable to both age-matched and level matched controls, though her rhythm PR was superior to the age-matched controls and her tonal PR was a little lower. EA has considerable experience in music lessons, having started with group classes at age three. Rhythm activities in her group class included singing and clapping rhythms in 2/4, 3/4, and 4/4 time. Her mother, RA, commented that "[the children] would do like, you know, rhythms and stuff like that, and she's not too bad… she was better with those." EA and her mother spoke about regularly about EA's enjoyment of singing, and their encouragement of this activity through the purchase of a karaoke machine. Perhaps prolonged exposure to rhythm training through early music group classes, and familial encouragement to pursue singing as a hobby influenced EA's average to superior performance in audiation.

Discussion

The aim of this study was to explore the case of a candidate for dysmusia, EA, through interviewing her and her family to understand the context in which she is learning music, and testing her on processing speed, motor, music reading, writing, sight-reading, and audiation tests. While the trail making test confirmed EA's existing processing speed deficit associated with her dyslexia diagnosis, her performance on the music reading, writing, sight-reading, and auditory tests demonstrated slight differences from the control group. In the interviews, we learned that EA's supportive family is involved in her musical success, and her positive attitude towards learning contributes to her dedication to piano practice. Based on the quantitative and qualitative evidence, we consider it unlikely that EA has dysmusia. As our stance is that dysmusia and dyslexia are likely related, but there is room for domain specificity, we discuss EA's results from both points of view.

In the literature, there is some evidence of musicians with dyslexia who experienced challenges with music reading acquisition at the advanced level or career sustainment. EA was playing at Conservatory Canada grade three at the time of testing, which is not quite at an intermediate level. In the case study by Vladikovic (2013), her adult student, Cathryn, only began experiencing significant difficulties with sight-reading, rhythm, and hand-coordination once she began playing advanced repertoire. Vladikovic speculated that her giftedness (confirmed in childhood through testing) led to the invention of coping strategies that had worked until that point in time. Backhouse (2001) interviewed a pianist, who, despite having a successful career as a soloist and collaborative pianist, quit the latter due to burn out caused from the constant sight-reading of new repertoire. In our study, EA's sight-reading evaluation differed from the controls in the rhythm parameter, as EA took pauses after nearly every beat. Given the protocol of little to no preview, EA was forced to process all the musical symbols simultaneously. While EA's performance on the music reading, 2-notes condition was lower than the control group, it could be attributed to lack of familiarity with the blocked notes presentation, and the short 2-second duration of the notes on the screen. In the reality of her music lessons, EA would be given more time to preview new music, which would give her more time to process the score. Based on the interviews, as well as communication with EA's piano teacher and viewing her last piano exam report, sight-reading is not a current challenge. Whether or not EA will experience difficulties with sight-reading that meaningfully impact her learning progress remains to be seen.

Not all musicians with dyslexia described in the literature experience or have experienced difficulties with music reading, and moreover demonstrate superior musical ability. Nelson (2014) interviewed Reggie, a violinist whose dyslexia impacted neither his music learning nor his career as a concertmaster. Reflecting on his childhood, he was considered a slow reader, and he also had difficulties with some aspects of mathematics such as reversing numbers. Lea (2008) described difficulties with music reading with respect to the guitar, but not to the cello, positing that music reading difficulties could be instrument specific. EA outperformed the control group in the writing tests as well as in the rhythm audiation parameter of the IMMA. Moreover, EA's superior performance on the writing tests contradicts her diagnosis of dysgraphia, which affects her handwriting.

EA's performances could contribute to evidence that dysmusia is a domain specific condition. In a review by Cuddy & Hébert (2006), music- and text-reading difficulties were found to be dissociated in several musicians following a stroke, which led to the hypothesis that music reading difficulties could be studied separately from text reading. In particular, the authors reference the case of a blind organist in a study by Signoret and colleagues (1987), who lost the ability to read the alphabet, but retained the ability to read music, even though Braille is common to both. To diagnose an individual with a specific learning disorder such as dyslexia, they must demonstrate reading achievement scores of at least 1.5 SD below the population mean (American Psychiatric Association, 2013). In our study, EA's music reading scores were less than 1.5 SD below the mean on both the 1- and 2-note conditions, and superior to the mean on the 3-note condition. Perhaps the main cognitive deficit in dysmusia differs from dyslexia. For example, Peters, Op de Beeck, and De Smedt (2020) describe phonological processing as the main cognitive deficit in dyslexia, and numerical magnitude processing as the main deficit in dyscalculia. While the likelihood of comorbid dyslexia and other learning disorders is about four times as higher compared to the typically developing population, it should not be assumed that a child with dyslexia has other learning difficulties (Landerl & Moll, 2010).

Conclusion

In conclusion, we explored the case of EA, a young piano student with dyslexia with respect to her candidacy for dysmusia through the administration of both interviews as well as tests for processing speed, motor skills, music reading, music writing, music sight-reading, and audiation. Interview data revealed two salient themes, that EA’s familial involvement in her music learning and life as well as her positive attitude towards learning could contribute to her performance on the music tests. While EA’s processing speed test confirms the deficit that is associated with her diagnosis of dyslexia, her performances on all the music tests are comparable to matched controls for age and music playing level, with some slight exceptions. EA’s music reading scores were slightly lower than controls when notes were named aloud, and when the task included decoding notes in solid presentation. However, her scores were slightly higher than controls for decoding 3-note patterns in broken presentation, as well as for music writing. For music sight-reading, EA’s made more rhythm errors compared to an age- and level-matched control, though our study’s test did not include preview time. audiation, EA’s PR was a bit lower than controls for tonal, but not for rhythm, in which her PR was superior. We do not consider EA to have dysmusia, as her scores did not differ substantially from those of the controls. Our results contribute to evidence that dysmusia does not present itself in all cases of dyslexia, and it may be researched further as its own domain specific condition.

Limitations

A limitation of this study is the size of the control group to which we compared our case. While a larger sample would have perhaps been more representative of the general population, the homogeneity of the group of piano students within specific playing expertise and age was considered a starting place for dysmusia exploration. Another limitation is the variance of solid and broken presentation in the music reading tests, which may have had a slight impact on EA's performance. However, this could be interpreted as an avenue for building on our study design and considering note presentation as a potential factor for dysmusia research.

Implications for further research

Further research into dysmusia could go in two avenues. First, researchers could continue to develop the baseline data of participants with neither dyslexia nor suspected dysmusia, while comparing data to more children with diagnosis of dyslexia. This would support the notion that dysmusia may often cooccur in dyslexia and would eventually yield more participants with significant difficulties with music reading. Second, more explorations into the possibility that dysmusia is domain specific could include interviews and testing of children with difficulties in music reading who do not have diagnoses of dyslexia.

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Chapter 6: General Discussion

Overview of Purpose

The goal of this dissertation was to explore dysmusia as its own entity in young piano students, from forming an understanding of how it presents itself based on literature to creating a baseline against which suspected cases can be compared, and this was done using four research purposes. The first purpose was to organize the literature on dysmusia into clear manifestations and indicators that could be quantifiably measured. The second purpose was to review available tests for each manifestation of dysmusia that were appropriate for a demographic of young piano students. The third purpose was to explore music reading, music writing, and audiation test performance in a group of young piano students with neither suspected dysmusia nor dyslexia. Finally, the fourth purpose was to focus on a candidate for dysmusia – a young piano student with dyslexia – to compare her test results to our baseline as well as to normalized data and frame her test performance within the broader context of her learning environment through analysis of interviews. The results of these purposes have been presented in article format in Chapters 2 to 5. The remainder of Chapter 6 will present the overall dissertation findings. The first section of the discussion summarises each articles' results and discusses how the article findings relate to one another. The next sections present implications of the dissertation, followed by strengths and limitations. The final section of Chapter 6 concludes with suggestions for further research.

Summary of Findings

The first investigation is presented in Chapter 2, which identified the manifestations and indicators of dysmusia according to a framework belonging to the British Dyslexia Association (BDA). From our categorisation, we found four manifestation groupings in which to sort the indicators of dysmusia: general indicators, reading, written work, sequencing, and skills. We added some music-specific difficulties under reading, written work, sequencing, and skills. Among musical instrument group types, pianists' reports appeared in the literature the most often. Some indicators, while observable, also point to a shared deficit with dyslexia—poor auditory skills, forgetting note names, slow reading progress, difficulty with dictation, and difficulty remembering anything in a sequential order. The common deficits concern processing speed, auditory skills, working memory, visual-spatial skills, and motor skills.

Our understanding of dysmusia is largely based on reports from musicians with a dyslexia diagnosis though we assume neither that every individual with dyslexia will also experience dysmusia nor that every musician with dysmusia has dyslexia (Cuddy and Hébert, 2006), which is also true for dyslexia and dyscalculia (Kucian & von Aster, 2015). Results from article one justified decisions in subsequent articles in the dissertation. In article one, we learned that most reports were coming from pianists and reflections on childhood piano lessons, which justified our choice to explore measurement possibilities in the specific population of young piano students in article two. In article one, results showed that several musicians struggling with music reading also struggled with music writing and auditory skills, which were our focus points for measurement in article three. Finally, several cases of musicians described in article one were described in case study format, either from qualitative or quantitative approaches, but not both. This influenced our decision to use a mixed-methods approach for article four, which was the case study of a candidate for dysmusia.

The second investigation is presented in Chapter 3, which reviewed available tests to quantifiably measure the manifestations and indicators of dysmusia in populations of young piano students. Concerning music reading, the primary manifestation of dysmusia, we found no tests apart from those developed in our own laboratory that comprised the note identification, note playing, and sight-reading components that we intended to measure. For music writing, for which indicators often cooccur with those of music reading, we found no tests at all. To accommodate for this gap, we designed music writing tests for copying and dictation, as is commonly measured in language (Re & Cornoldi, 2015). The search for auditory skills tests yielded several choices from nearly 100 years ago to present day, though only Gordon's *Measures of Music Audiation* (Gordon, 2001) has been used in studies of children with dyslexia, therefore it is sensitive to children with learning differences. To test for processing speed and motor skills the *Comprehensive Trail Making Test* (Reynolds, 2019) and the *Purdue Pegboard Test* (Lafayette Instruments) were selected.

The third investigation is presented in Chapter 4, which created a baseline for music reading, music writing, and audiation tests in young piano students with neither suspected dysmusia nor dyslexia. For mean scores of tests, we found that music reading and writing test performance generally improved with musical expertise. Our participants' sight-reading scores appeared appropriate for their playing levels, with the beginner group reaching piece three at maximum, and the more advanced group reaching approximately piece five. For test comparisons, the results showed that the music reading and writing tests were of comparable difficulty when the condition was note naming (one note) for music reading and note copying and dictation (one note) for music writing. However, when the music reading conditions required playing notes at the piano (two and three notes), the median performance was lower compared to music writing (two note dictation and three note copying). reaching statistical significance. Regarding music reading (sight-reading) and audiation, we found no statistically significant interaction. However, upon visual inspection, within the participant sample, more high proficiency sight-readers had higher tonal median scores compared to the low proficiency group. However, rhythm audiation performance appeared to have a more variable distribution in both groups. The results of article three create a baseline to which future studies can add and against which we can compare suspected cases of dysmusia.

The fourth investigation is presented in Chapter 5, which described the candidature of a young piano student for dysmusia, based on interviews as well as test performance data. From interviews with the case, EA, and her mother, RA, we learned that EA's family support plays a big role in her day to day life, especially in her music learning, and EA's positive attitude towards learning influences her dedication to practice. EA's diagnosis of dyslexia was apparent in her trail making performance, as her processing speed indexes were in the first percentile. However, her motor skill performance, as well as all her music performances, do not suggest that she has dysmusia. Regarding music sight-reading, in which dysmusia should be most apparent, EA performed comparably to matched controls, albeit with more rhythm errors. Article four is unique because it focuses on building a case for dysmusia around both qualitative and quantitative data, and does not assume that dysmusia must co-exist with dyslexia.

Research Implications

The results of this dissertation contribute to the first steps in understanding dysmusia, proposing a way forward to identifying students who may be experiencing it. As dysmusia is likely related to dyslexia, which is a learning disability, the tests covered in this dissertation are likely to misidentify or overidentify children as having dysmusia until subsequent populations are tested, because this is a concern in all new screening tools for learning disabilities (Chatterji, 2003). Implications of misidentification and overidentification could lead to stigmatization of a learning difference that does not exist. Furthermore, one must consider the context of musical development before determining that a child has a learning difference (McPherson & Hendricks, 2010). In a study of professional musicians by MacNamara, Holmes, and Collins (2006), the musicians reported similar characteristics in their early musical learning, which included: passion for learning, commitment to practice, musical lifestyle beyond the music lesson, and support network. Related to article 4 of this dissertation, the case participant's learning environment contained the same characteristics. Had her test performance been suggestive of dysmusia, it could not have been for lack of attaining these characteristics shared by successful musicians. Subsequent studies could explore if children who are presenting manifestations of dysmusia have demonstrated the same or different characteristics, before potentially misidentifying them.

On one hand, it is not the intent to separate students with suspected dysmusia from students whose music reading progress is typical, rather, to create a more appropriate learning environment. In research in dyslexia, the label of "dyslexia" may reduce teachers' sense of self-efficacy regarding their abilities to teach children with the diagnosis compared to children with non-specific reading difficulties (Gibbs & Elliott, 2014). Children with dyslexia can feel the impact of teachers' perceptions of their dyslexia in comparing them to other students, along with comparisons from family members and peers (Glazzard, 2010). Among music students, low self-efficacy may negatively impact musical performance (McCormick & McPherson, 2006). Thus, it may be best to encourage inclusive music learning practices from the very first music lesson. Hammel, Hickox, and Hourigan (2016) propose three guiding principles: meeting individuals' learning needs, having multiple access points for activities of varying difficulties, and preparing adequate conditions for learning. Specific examples of these principles include encouraging a culture where mistakes are normalized and expected and giving specific praise for success and improvement, including games that are appropriate to the needs of the student in the context of music making, and beginning each lesson with a musical exploration activity that permits the student to warm up and prepare for the lesson (Anderson, 2016).

On the other hand, the discovery of the label of dysmusia could be a relief to musicians, as it could provide an explanation for their difficulties with music reading that are not related to dedication to practice, intelligence, or talent. With no pre-existing literature about musicians expressing relief with a possible diagnosis of dysmusia, inspiration can be taken from individuals receiving a dyslexia diagnosis. In an editorial by Allan (2018), John, a barber, experienced a life-changing perspective shift following his dyslexia diagnosis at age 35. Words he used to describe himself prior to the diagnosis included “stupid” and “wrong” and he dropped out of high school. However, following his diagnosis, John continued his education and achieved a post-secondary diploma. On her blog, Frost (2017) reflected on being diagnosed with dyslexia as a child, which connected her with a tutor who encouraged her to pursue a creative career (not specified). The diagnosis of dyslexia and kind tutor gave her armor against school teachers who accused her of being lazy.

In cases of musicians with a pre-existing diagnosis of dyslexia, there may be an apprehension to begin music lessons out of fear of being judged for possible reading difficulties, but a knowledgeable teacher can emphasize students’ strengths to facilitate continued learning. For example, as reported by Oglethorpe in Miles, Westcombe, and Ditchfield (2008), cello student Jenny was apprehensive about music lessons because she was worried that any difficulties in music reading would prevent her from succeeding. However, because her music teacher understood that a dyslexia diagnosis could have an impact on music reading, her lessons were customized to her needs, and she flourished with her exceptional auditory perception ability. In an interview with Nelson (2014), jazz musician Danny reflected that his dyslexia diagnosis gave him an opportunity to explore his strength in improvisation at his music lessons, which became the focus of his career.

While music teachers may not be aware of dysmusia as its own entity, pedagogical methods have been created to cater to students with learning differences such as dyslexia. Notably, the Colour-Staff Method designed by Margaret Hubicki in the 1960s is a method to teach piano to children with dyslexia (Hubicki, 2005). Other methods which are marketed for inclusive learning for all children include Music for Young Children (Music for Young Children Organization) and Kindermusik (Kindermusik International). The popularity of these methods reflects a shift in music teachers' perspectives. As several musicians with dyslexia have expressed that their music teachers assumed their difficulties were due to lack of practice or laziness (Miles & Westcombe, 2001; Miles, Westcombe, & Ditchfield, 2008), the current generation of students have more opportunities to find teachers who encourage their music learning.

Finally, parents of children who are suspected of having dysmusia would feel reassurance in the fact that their children's music learning differences do not impede them from pursing their passions. Given the lack of awareness of parents surrounding dysmusia, one can imagine the responses based on literature about dyslexia. Riddick (2010) provides several anecdotes from parents upon discovering their children's dyslexia diagnoses following a survey. Out of 22 mothers, 20 expressed relief. One mother commented, "Such a relief! It was the first time he wasn't lazy, wasn't stupid. It wasn't his fault" (p. 82). Moreover, the mothers surveyed reported feeling guilty for not having their children assessed sooner.

Strengths and Limitations

A strength of this dissertation is the multiple ways in which data were collected. In articles one and two, qualitative articles were gathered adhering to review procedures. In article three, quantitative data were collected through Musical Instrument Digital Interface (MIDI), through manual data entry (from observing music reading videos, entering music writing responses) and through a computer program for the auditory skills test. Article four used interview data in addition to the same sources as article three. Article one considered the perspectives of musicians of varying skill levels, careers, and instruments, and teachers with varying experiences and observations. Article two considered tests from varying time periods within the last 100 years, and research fields including music, psychology, education, and sciences. In article three, our quantitative data focused on the specific group of young piano students with neither dyslexia nor suspected dysmusia to create a baseline for music reading, writing, and audiation tests. In article four, we collected the same test data, but from a specific case of a young piano student with a diagnosis of dyslexia, to which we made direct comparisons. Through interviews with the case and her parent we gained information about her musical life as well as home and school environments, which gave more meaning and context to her test performance.

A second strength of this dissertation is the combination of qualitative and quantitative analysis approaches. Articles one and two employed two different reviews. a systematised review of qualitative evidence and a critical review, both of which had specific procedures. Article three included both simple analyses (sight-reading analysis according to a scale, writing test analysis according to a rubric, calculating test means) as well as non-parametric statistical tests (paired sign test and Mann-Whitney U). Article four combined both quantitative and qualitative approaches to be complementary, using the strengths of each. Through comparing the case participant with dyslexia to matched controls from article three, and to normalized data, we can generate hypotheses about how other children with dyslexia might perform on the tests compared to the general population. However, our qualitative findings from the interviews created a context around the case's learning environment that could explain her performance results.

A third strength of this dissertation is the focused scope, as, within each article, the scope was justified by the available literature. In article one, literature searches were focused on dysmusia, dyslexia and music, and music reading, which avoided misrepresenting what dysmusia could look like. In article two, literature searches were focused on the manifestations of dysmusia identified in article one, resulting in a list of possible avenues for measurement, avoiding irrelevant tests. In article three, the decisions to recruit only piano students, and to test for music reading, writing, and audiation were informed by article one, establishing a connection among the papers. Finally, in article four, the selection of a case participant with dyslexia comes from article one, wherein most musicians reporting difficulties with music reading also had a diagnosis of dyslexia. The inclusion of case-control reporting to normative data for the pegboard and trail making test comes from article two.

In contrast, the scope of the dissertation may be viewed as a limitation. In article one, few sources reviewed were published in peer-reviewed journals. However, this inspired the need to measure dysmusia manifestations. In article two, there were few available tests for music reading to review, and none for music writing, though this was interpreted as an opportunity to explore how laboratory developed music reading and writing tests interacted, given how important these difficulties are in the context of dysmusia. In article three, our participants, while homogenous in their capacity as piano students without dyslexia, came from a variety of musical training backgrounds including reading-based and ear-based. The variance reflects the broader population of piano students worldwide whose training is not limited to one particular method. In article four, the scope of the case study was limited to one piano student. However, this decision was deliberate, as it is unreasonable with the state of the dysmusia literature to expect that all individuals with dyslexia will perform in a similar way on the tests. Rather, gathering plentiful information about a singular case is useful for generating questions about the role dyslexia may or may not play in dysmusia.

A second limitation of this dissertation is study location. In article one, literature gathered on dysmusia was not limited by country, and reports were largely from North American and European authors. However, in article three, the study was focused on piano students located in the Ottawa-Gatineau region, and in article four, the case participant was located in a western city in Canada. While the population may not be representative, it was important to have homogeneity among participants in this exploratory research phase. Subsequent studies can replicate findings with populations of children in other regions and countries. For example, in a study of amusia in children, Peretz and colleagues (2013) administered their tests to children located in Canada and in China, once their tests had generated baseline data.

A third limitation of this dissertation is the participant sample. As dysmusia is understood as a possible relative of dyslexia, it would have benefitted the project to include more participants with a dyslexia diagnosis, both use as a comparison group in article 3, as well as to create a collective case study in article 4. However, we cannot make any claims about measuring dysmusia without focusing on developing baseline data. Furthermore, focusing on a singular case provided room for questioning the relationship between dysmusia and dyslexia as each comparison made between the case and the controls.

Future Research

Continued Baseline Testing

As dysmusia is a relatively new topic with piano pedagogy, there are several avenues through which future research could be undertaken. First and foremost, larger participant groups of young piano students can contribute to the baseline test results reported in article three. As the baseline group in article three had no diagnoses of dyslexia, it is important to continue this exclusion criteria as dysmusia is still often discussed as a relative to dyslexia. Considering participants from a variety of music instruction backgrounds, including those reported in article three and beyond would add to representation and increase replicability over time. Or, another exploration with baseline participants could limit cohorts by instructional methods, to test if musical background affects test performance. For example, in article three, the visual inspection of tonal audiation showed that more participants in the high proficiency sight-reading group had a higher PR compared to the low group, perhaps suggesting a sensitive to musical training backgrounds, but that is uncertain without more data. As discussed in the limitations, future research could consider larger groups of participants from varying language backgrounds.

In tandem with participants who could contribute to the baseline, future studies could involve more participants with diagnoses of dyslexia. As discussed in article one, that dysmusia has been largely reported by musicians with dyslexia, it would be interesting to measure whether there are statistically significant differences in test performance between children with and without dyslexia. In article four, the case participant with dyslexia was not demonstrating difficulties with music reading as noted by her parents and her piano teacher. Her performances on the music reading and sight-reading test reflect this assessment, as the scores were not significantly different. In the literature, not all musicians with dyslexia are reporting difficulties. For example, in the case study by Nelson (2014), not all musicians interviewed struggled with music reading, or had any significant musical challenges. Therefore, in studies of children with dyslexia, it would be important to consider them as individuals and not make the assumption that every child has dysmusia. Perhaps several case studies modelled after article four could consider both test performances as well as learning environment.

Continued Test Exploration

A second possible direction for future research is exploring more conditions of the music reading and writing tests. In article three, the music reading to writing pairings were only focused on C position and the treble clef because the intent was to create a baseline for beginner as well as intermediate to advanced children. However, it would be interesting to see how performance would be affected with the added complexity of bass clef and G position conditions. Beginner participants could be included so long as they were familiar with the bass clef and playing in G position on the piano. Additionally, researchers could create conditions to include other key signatures, accidentals, or expression markings. The additional symbol conditions would be better suited to more advanced players who are accustomed to encountering them on the score. For example, in the case study by Hébert and colleagues (2008), the adult musician who was tested on symbol discrimination was on par with her peers without dyslexia until the symbols increased in complexity, at which point her performance declined. In the case study by Vladikovic (2013), her adult piano student did not struggle with music reading until she transitioned from intermediate to advanced repertoire.

A third option for future studies could be the inclusion of a vision test in the procedure. According to parent reports, none of the participants in article three experienced vision challenges, and in article four, the case participant was accustomed to not wearing her glasses during her piano lessons and practice at home, despite wearing them at school. Visual deficits frequently co-occur in children with dyslexia compared to controls without dyslexia (Raghuram et al., 2018) and measuring eye-movements during reading tasks is a way different eye movement patterns between children with and without dyslexia have been detected (Moiroud et al., 2018; Vinuela-Navarro, Erichsen, Williams, & Woodhouse, 2017). Participants could receive a visual acuity test and the results could inform whether their data is included in the baseline. For participants with suspected dysmusia, researchers could track their eye movements to understand their reading practices. In a study by Mantei and Kervin (2017), a child with reading difficulties wore eye-tracking glasses during text reading activities and the fixations showed his tendency to focus on the first letters in words. Perhaps researchers could find similar or different tendencies for music sight-reading.

Considerations of Musical Comprehension

A fourth option for developing research studies in dysmusia is to consider the role that musical comprehension could play. One could explore if a musician must understand the music to be able to read it fluently. In the third and fourth articles of this dissertation, Gordon's *Measures of Music Audiation* tests were included, which test participants' capacity to ascribe meaning to sounds (melodies and rhythms) such that they can make judgements about what is heard (i.e., discerning two melodies as the same or different). With a larger participant sample and a focus on making links between music reading accuracy and audiation scores, the extent to which comprehension influences dysmusia could be understood. If such an influence exists, pedagogical approaches, especially with children with learning differences such as dysmusia, it would lend scholarly support to learning methods that are ear-focused prior to the introduction of music reading.

An approach to considering comprehension as a part of dysmusia could be borrowed from dyslexia research. According to Clarke and colleagues (2010), the simple view of text reading comprising two distinct processes of decoding and comprehending means that these are two separate areas in which children can struggle. A child with dyslexia may be able to comprehend text despite challenges with decoding fluency. However, a child without dyslexia may have difficulties with comprehending text, which is another type of specific learning impairment. In music study, this distinction is not clear. Future studies could use a longitudinal approach to ensure that a cohort of children have a similar musical foundation, and use the tests used in this dissertation to explore if music reading association is related or not to audiation.

Conclusion

This dissertation explored dysmusia in musicians, particularly in young piano students, from both quantitative and qualitative angles. While all four articles in the dissertation relate dysmusia to dyslexia (Miles & Westcombe, 2001; Miles, Westcombe, & Ditchfield, 2008), it should not be assumed that one's diagnosis of dyslexia means that they also could experience dysmusia (Cuddy & Hébert, 2006). In article one, music reading and writing difficulties were often cooccurring according to musicians' reports, and this expectation was not reflected in the case study in article 4, as the case's music reading scores were similar to controls, and she outperformed the controls on music writing. Furthermore, as dyslexia is often associated with an auditory skills deficit as presented in article one, this was expected to be found in the case study. However, this was not true, as her percentile ranks for both pitch and rhythm audiation were similar to the controls. Whether the case's scores were influenced by musical expertise (Weiss, Granot, & Ahissar, 2014) as proposed in article 3, or support the theory that dysmusia is a domain specific condition, as discussed in article 4, are topics for future exploration.

Combined, the four articles of this dissertation lay the foundation for research in dysmusia with young piano students. Through the organization of manifestations and indicators to deepen understanding of what dysmusia could be, the selection of relevant tests with a specific demographic, the creation of a baseline with participants with neither dyslexia nor suspected dysmusia, and the exploration of a case participant with dyslexia, the reader will acknowledge that dysmusia is a new area of scholarly pursuit with respect to young piano students. While it is likely that musicians with dyslexia will resonate with the difficulties experienced by musicians' reports in article one, they should not assume that they have dysmusia. Rather, understanding dysmusia as a relative of dyslexia is a starting point for both the musician who is having difficulties with music reading, as well as for the piano teacher whose students are not progressing in their music reading acquisition at the same pace as their peers. Ultimately, awareness of, and identifying manifestations and indicators of dysmusia in young piano students could lead to a fresh learning perspective that is supportive and conducive to musical success.

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Chapter 8: Appendices

Appendix 8A: Ethics Certificate

25/02/2022

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE | CERTIFICATE OF ETHICS APPROVAL

Numéro du dossier / Ethics File Number	S-12-19-5306
Titre du projet / Project Title	Exploring the possible manifestations of dysmusia in piano students
Type de projet / Project Type	Thèse de doctorat / Doctoral thesis
Statut du projet / Project Status	Renouvelé / Renewed
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	11/03/2021
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	10/03/2023

Équipe de recherche / Research Team

Chercheur / Researcher	Affiliation	Role
Meganne WORONCHAK	École des sciences de l'activité physique / School of Human Kinetics	Chercheur Principal / Principal Investigator
Gilles COMEAU	Département de musique / Department of Music	Superviseur / Supervisor

Conditions spéciales ou commentaires / Special conditions or comments

Appendix 8B: Letter of Invitation

uOttawa

Université d'Ottawa
Faculté des sciences de la santé

École des sciences de l'activité physique

University of Ottawa
Faculty of Health Sciences

School of Human Kinetics

Ottawa, September 2021

Invitation to participate

My child and I are invited to participate in a study about developing and assembling tests to assess children's music reading, auditory perception, and music writing skills. Here are the details.

Objective: The objective of the project is to assess the music reading, music perception, and music writing skills of piano students between the ages of 6 and 11 and 12 and 15.

Inclusion criteria: My child must be between the ages of 6 and 15, be reading music at a grade 1 RCM level or equivalent and be able to communicate in English.

Cost: There will be absolutely no cost. If you encounter parking fees, you will be reimbursed.

What my child and I will be asked to do: The project will be carried out as two sessions of music and puzzle tests or "games" with my child, or one session with a break if my child is at least 10 years old. On the first day, the test administrator will guide my child through a battery of music reading, music writing, and puzzle games. On the second day, my child will complete a music perception game, along with more puzzle games. All games are designed for the age and music reading level of my child and may challenge them in a similar way to their music lessons. My child will be encouraged to do their best. Each session will last approximately 45 minutes. During the first session, I will be asked to fill out a questionnaire taking about 10-15 minutes. This questionnaire covers musical history, musical motivation, information that can help the research team understand how my child learns in general, and demographic information.

Who will carry out the tests: The tests will be carried out by Meganne Woronchak (principal investigator) of the Piano Pedagogy Research Laboratory. She has experience teaching piano to young children.

When and where the sessions will be carried out: I will be contacted by the principal researcher (Meganne Woronchak) by telephone or email and together we will make the necessary arrangements concerning the date and time of the sessions. The sessions will take place at the Piano Pedagogy Research Laboratory.

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Faculté des sciences de la santé

École des sciences de l'activité physique

University of Ottawa
Faculty of Health Sciences

School of Human Kinetics

Voluntary participation, anonymity and confidentiality: My child and I are participating voluntarily and can chose to not participate at any time. All information provided by my child and I will remain strictly anonymous and confidential. Only authorized collaborators / researchers of the Piano Pedagogy Research Laboratory will have access to the data provided (Meganne Woronchak, Gilles Comeau). The information provided by my child and I will remain confidential.

This study has been granted ethics approval by the Research Ethics Board of the University of Ottawa. For any information regarding ethical issues in research, feel free to contact the Office of Research Ethics and Integrity, University of Ottawa, Room 154, Tabaret Hall, 550

Cumberland Street, Ottawa, Ontario K1N 6N5. (Tel.: 613-562-5387; Email: ethics@uottawa.ca)

Public Health Considerations: All research takes place at the Piano Pedagogy Research Laboratory, which follows current public health guidelines of mandatory vaccination for all campus visitors ages 12 and over, mandatory-self assessment for all campus visitors, physical distancing, mask-wearing, and regular surface cleaning and disinfecting.

Consent: I will discuss this study with my child and if interested we will send an email to:

Meganne Woronchak, PhD Candidate, Principal Investigator
[redacted]

Dr. Gilles Comeau, Research Supervisor
[redacted]

Sincerely,
Meganne Woronchak
Dr. Gilles Comeau

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Appendix 8C: Consent Forms

Article 3

uOttawa

Université d'Ottawa
Faculté des sciences
de la santé

École des sciences de
l'activité physique

University of
Ottawa
Faculty of Health
Sciences

School of Human
Kinetics

Assent form for children

Title of Study: The assessment of music reading, music perception, and music writing skills in young piano students

Principal Investigator
Meganne Woronchak, PhD candidate
[redacted]

Research Supervisor
Dr. Gilles Comeau
[redacted]

My name is Meganne Woronchak and I am a PhD candidate at the University of Ottawa. I would like to find out how you read, listen to, and write music. There will be two days where you will play music games at the Piano Pedagogy Research Laboratory at the University of Ottawa. In total, you will play games for 1.5 hours. On the first day, you will be asked to play some music reading games while sitting at the piano, like playing the notes that you see on the treble clef. The music will appear on a computer and might look like a video-game. Then, you will take a break and be offered water. Next, you will be asked to play write out some notes on paper while sitting at a desk. You will use a pencil like you do when you write and draw at school. Then, you will complete some short puzzle games. There will be a video-recording only while you are playing the games at the piano. You can stop participating at any time without any negative consequences to my study or to your piano lessons. The second day, you will sit at a desk and play another music writing game, followed by a music listening game using a computer, as well as more puzzle games.

There is no right or wrong way to play these music games. It is really up to you to decide. What I am interested in is that you do your best. This will stay between you and me. You can contact me or my research supervisor, Dr. Gilles Comeau with any questions. It is entirely up to you to decide whether to participate in my project or not. You do not have to help me if you do not want to. You do not have to participate even if your parents want you to participate.

There are two copies of this form. You must sign both to participate in my study. You keep one copy, and I keep the other.

hkesap@uottawa.ca

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École des sciences de
l'activité physique

University of
Ottawa
Faculty of Health
Sciences

School of Human
Kinetics

Do you agree to participate in this project? Yes_____ NO_____

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Faculty of Health Sciences

School of Human Kinetics

Consent Form for Parents

Title of the study: The assessment of music reading, music perception, and music writing skills in young piano students

Principal Investigator
Meganne Woronchak, PhD candidate
[redacted]

Research Supervisor
Dr. Gilles Comeau
[redacted]

Invitation to Participate: My child and myself are invited to participate in the aforementioned research study conducted by doctoral candidate Meganne Woronchak for her doctoral thesis, supervised by Dr. Gilles Comeau.

Purpose of the Study: The purpose of the study is to learn about how music reading skills may or not be related to other skills: music perception and music writing while considering cognitive skills in the form of puzzles. The researchers inform me they know that for text reading, it is related to auditory perception and writing abilities among children. They would like to learn if the same relationship is true in music reading. They will learn if this relationship is true through administering music reading, auditory perception, and music writing tests.

Participation: My child's participation will consist essentially of attending two sessions, or one session if my child is at least 10 years old, with a mandatory break. Both sessions are conducted in-person at the Piano Pedagogy Research Laboratory at the University of Ottawa (Room 204, 50 University Private, Ottawa) approximately 45 minutes each. My child's participation consists of reading music while sitting at a piano and writing music while sitting at a desk, listening to musical samples on a computer and responding via mouse-click while sitting at a desk, and completing short puzzles games at a desk.

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My participation includes completing an intake questionnaire for my child, taking approximately 15 minutes on the first session. This questionnaire is called "Survey of Musical Interests" and is a music motivation questionnaire used by the Piano Pedagogy Research Laboratory. This questionnaire will help us observe any possible relationship between music motivation and music reading. Meanwhile, my child will be asked to complete music tests, referred to as "music games" spanning the two-sessions. During the first session, my child will be assigned a numerical tag to show to the video camera for the music reading tests at the piano. Only the music reading tests will be recorded. On the first session, my child will sit at a piano and read music notes on a computer screen, taking approximately 30 minutes. Then, my child will have a short break, during which refreshments will be provided for free. Next, my child will sit at a desk and complete music writing tests with paper and pencil, taking approximately 10 minutes, and some short puzzle tests, taking about 5 minutes. On the second session, my child will sit at a desk and complete a music listening test using a computer and mouse, taking about 20 minutes, followed by short puzzle tests, taking about 20 minutes. At the end of the second testing session, my child will receive a short debriefing from the principal investigator. The principal investigator will explain that my child did very well playing the music games, and that the games were meant to be a little difficult.

Risks: My child's participation in this study will entail that they complete three somewhat challenging music tests (music reading, music writing. and auditory perception). This may cause my child to feel nervous about making mistakes and feel tired from sitting at the piano and desk. I have received assurance from the researcher assistant that every effort will be made to minimize these risks. Regarding potential nervousness, the principal investigator will encourage my child to do their best and explain to my child there is no incorrect way to play, read, or write for these music games, ensuring to refer to them as games always. After the final music game during the in-person session, the principal investigator will provide my child with a short debriefing, explaining to them that the music games were meant to be a bit challenging, and they did very well. Regarding tiredness, the research assistant will tell my child they can take a break or stop the music games if they are feeling tired. During each session, there will be a scheduled break for refreshments.

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Benefits: My child's participation in this study will benefit music researchers who are studying music reading development in children. My child's participation contributes to our understanding of the relationship between music reading, music writing, and auditory perception. The results of our study will be able to shape how music reading is taught among the broader piano teaching community.

Confidentiality and anonymity: I have received assurance from the principal investigator that the information I will share, and the data from my child's participation will remain strictly confidential. I understand that the contents will be used only for analyzing how groups of children read, write, and perceive music. My and my child's confidentiality will be protected. The principal investigator will provide my child with a randomized numerical tag at the beginning of the first session, and this number will be attached to my child's data rather than their name or other personal identifiers.
Anonymity will be protected in the following manner. The principal investigator will store the data in a secure, password protected computer drive at the Piano Pedagogy Research Laboratory. Only the principal investigator and research supervisor will have access to the data files. My child's data from video recordings will be renamed according to your child's numerical identifier. Paper materials will only have your child's numerical identifier on them and will be stored in a secure box within the Piano Pedagogy Research Laboratory. My child's identity will not be revealed in publications.

Conservation of data: The data collected (intake questionnaire, video recording, Musical Instrument Digital Interface (MIDI) and paper materials) will be kept in a secure manner at the Piano Pedagogy Research Laboratory. The digital materials (video recording and MIDI) will be stored in a secure, password protected computer drive at the Piano Pedagogy Research Laboratory at the University of Ottawa. The hard copies (intake questionnaires, paper materials), will also be kept at the Piano Pedagogy Research Laboratory. It will be retained for five years following completion of the study.

Voluntary Participation: My child is under no obligation to participate, and if they choose to participate, they can withdraw from the study at any time and/or refuse to answer any questions without suffering any negative consequences (nervousness, fatigue). If my child chooses to withdraw, all data gathered until the time of withdrawal will be deleted.

Acceptance: I, _________________________, consent that my child can participate in the above research study conducted by Meganne Woronchak of the School of Human Kinetics, Faculty of Health Sciences,

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and Piano Pedagogy Research Laboratory, University of Ottawa, supervised by Dr. Gilles Comeau.

If I have any questions about the study, I may contact Meganne Woronchak or her thesis supervisor Dr. Gilles Comeau.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5
Tel.: (613) 562-5387
Email: ethics@uottawa.ca

There are two copies of the consent form, one of which is mine to keep.

Parent's signature: Date:

Principal Investigator's signature: Date:

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Debriefing Text For Piano Students

Title of study: Exploring the possible manifestations of dysmusia in piano students

Thank you for participating in this study! The goal of this study was to determine how young piano students learn to read music by exploring music reading, music perception, and music writing. In this study, you were asked to complete music games including music reading, writing, and perception as well as some short puzzle games. Your participation is not only greatly appreciated by the researchers involved, but the data collected from your music games could possibly help other children learn how to read music. By playing these games, we can gain a better understanding of which parts of music reading, perception, and writing are difficult and which are easier for children learning how to play piano. Knowing which parts of music reading, perception, and writing are difficult will help piano teachers be more effective at teaching you how to read music. Ultimately, our research will help us find a way to determine if piano students are having difficulties in music reading. We call this difficulty "dysmusia" or musical dyslexia. We are first learning about what dysmusia could look like and do not have enough information yet. The results of this study will help us create a screening tool that we can use in the future to help piano teachers more effectively teach their students. You were not informed of this at the beginning of the study because we did not want you to feel nervous or worry that you have dysmusia or difficulty reading music.

During this study, you were asked to play music games in an unfamiliar room, with a principal investigator you did not know, and with a video camera recording you. Some of the games were challenging. Maybe you felt nervous or stressed out because of the unfamiliar situation or the the challenging music games. Many musicians feel nervous when they have to read music in front of people. We wanted to design our music games to imitate activities that you might do with your piano teacher at your lessons. In this way, we can learn how you learn, and this can improve the experience of many other children learning piano.

With this new information, do you consent to us using your data in my research study?

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There are two copies of this form. You must sign both to participate in my study. You keep one copy, and I keep the other.

Yes___ No___

If you have any questions about this study, please contact us. I, Meganne Woronchak (principal investigator) can be reached at [redacted] My research supervisor, Dr. Comeau, can be reached at [redacted]

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Debriefing Text for Parents

Title of study: Exploring the possible manifestations of dysmusia in piano students

Thank you for participating in this study! The goal of this study was to determine how young piano students learn to read music by exploring music reading, music perception, and music writing. In this study, you filled out a questionnaire about your child's musical interests and motivations to study music. Your child was asked to complete music games including music reading, music writing, and music perception as well as some short puzzle games related to learning in general. You and your child's participation is not only greatly appreciated by the researchers involved, but the data collected from the questionnaire and the music games could possibly help other children learn how to read music. The data will help us understand which parts of music reading, music perception, and music writing are difficult, and which are easier for children learning how to play piano. Ultimately, our research will help us find a way to determine if piano students are having difficulties in music reading. We call this difficulty "dysmusia" or musical dyslexia. We are first learning about what dysmusia could look like and do not have enough information yet. The results of this study will help us create a screening tool that we can use in the future to help piano teachers more effectively teach their students. You were not informed of this at the beginning of the study because we did not want you or your child to feel nervous or worry that your child has dysmusia or difficulty reading music.

During this study, your child was asked to play music and puzzle games in an unfamiliar room, with a principal investigator they did not know, and with a video camera recording them at the piano. Some of the music games were challenging. Maybe they felt nervous or stressed out because of the unfamiliar situation or the challenging music games. Many musicians feel nervous when they have to read music in front of people. We wanted to design our music games to imitate activities that your child might do at their piano lessons. In this way, we can learn how your child learns, and this can improve the experience of many other children learning piano.

With this new information, do you consent to us using the data provided by you and your child in this study?

There are two copies of this form. You must sign both to participate in my study. You keep one copy, and I keep the other.

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Yes___ No___

Signature: ______________________________

If you have any questions about this study, please contact us. I, Meganne Woronchak (principal investigator) can be reached at [redacted] My research supervisor, Dr. Comeau, can be reached at [redacted]

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Article 4

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Assent form for children

Title of Study: Exploring the manifestations and indicators of dysmusia in young piano students

Principal Investigator
Meganne Woronchak, PhD candidate
[redacted]

Research Supervisor
Dr. Gilles Comeau
[redacted]

Research Assistant
Mikael Swirp
[redacted]

My name is Meganne Woronchak and I am a PhD candidate at the University of Ottawa. I would like to find out how you read, listen to, and write music, as a young piano student with dyslexia. Participation includes one day of music games (about 1.5 hours) and one day with an interview (about 1 hour). On the music games day, a research assistant will guide you through activities at your home. In total, you will play games for 1.5 hours. First, you will be asked to play some music reading games while sitting at the piano, like playing the notes that you see on the treble clef. The music will appear on a computer and might look like a video-game. Second, you will be asked to play write out some notes on paper while sitting at a desk. You will use a pencil like you do when you write and draw at school. Third, you will play music listening game using a computer. Then, you will take a 10-minute break. Finally, you will complete some short puzzle games. There will be a videorecording only while you are playing the games at the piano. You can stop participating at any time without any negative consequences to my study or to your piano lessons. There is no right or wrong way to play these music games. It is really up to you to decide. What I am interested in is that you do your best. On the interview day, you will have a discussion with the principal investigator via videoconference for about 1 hour. You will answer questions about your musical experiences. The session will be recorded through the videoconferencing application. Again, you can stop participating at any time without any negative consequences to my study or to your piano lessons. There is no right or wrong way to

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answer the interview questions. What I am interested in is your own experiences as a young piano student with dyslexia.

This will stay between you and me. You can contact me or my research supervisor, Dr. Gilles Comeau with any questions. It is entirely up to you to decide whether to participate in my project or not. You do not have to help me if you do not want to. You do not have to participate even if your parents want you to participate.

There are two copies of this form. You must sign both to participate in my study. You keep one copy, and I keep the other.

Do you agree to participate in this project? Yes_____ NO_____

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Consent Form for Parents

Title of the study: Exploring the manifestations and indicators of dysmusia in young piano students

Principal Investigator
Meganne Woronchak, PhD candidate
[redacted]

Research Supervisor
Dr. Gilles Comeau
[redacted]

Research Assistant
Mikael Swirp
[redacted]

Invitation to Participate: My child and myself are invited to participate in the aforementioned research study conducted by doctoral candidate Meganne Woronchak for her doctoral thesis, supervised by Dr. Gilles Comeau and assisted by Mikael Swirp.

Purpose of the Study: The purpose of the study is to learn about how manifestations (groups of related difficulties) and indicators (specific difficulties) of dysmusia (also known as musical dyslexia) appear in young piano students. The researchers inform me they know that for text reading in cases of dyslexia, it can be related to auditory perception and writing abilities among children. They would like to learn if the same relationship is true in music reading. They will learn if this relationship is true through administering music reading, auditory perception, and music writing tests.

Participation: My child's participation will consist essentially of attending two sessions. For my child, session one takes approximately 1.5 hours, and session two takes approximately one hour. Both sessions are conducted at my home. For session one, my child's participation consists of reading music while sitting at a piano and writing music while sitting at a desk, listening to musical samples on a computer and responding via mouse-click while sitting at a desk, and completing short puzzles games at a desk.

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My participation includes completing an intake questionnaire for my child, taking approximately 15 minutes on the first session. This questionnaire is called "Survey of Musical Interests" and is a music motivation questionnaire used by the Piano Pedagogy Research Laboratory. This questionnaire will help us observe any possible relationship between music motivation and music reading. Meanwhile, my child will be asked to complete music tests. During the first session, my child will be assigned a numerical tag to show to the video camera for the music reading tests at the piano. Only the music reading tests will be recorded. First, my child will sit at a piano and read music notes on a computer screen, taking approximately 30 minutes. Second, my child will sit at a desk and complete music writing tests with paper and pencil, taking approximately 10 minutes, and some short puzzle tests, taking about 5 minutes. Third, my child will sit at a desk and complete a music listening test using a computer and mouse, taking about 20 minutes. Then, my child will take a 10-minute break. Finally, my child will complete short puzzle tests, taking about 20 minutes. For session two, my child will participate in an interview with the principal investigator via videoconferencing. My child will answer questions about their musical experiences as a young piano student with dyslexia. At a separate time, I will participate in an interview with the principal investigator via videoconferencing for about an hour. I will answer questions about my musical experiences, my child's musical experiences, and my child's learning experiences. Both interviews will be recorded via the videoconferencing application.

Risks: My child's participation in this study will entail that they complete three somewhat challenging music tests (music reading, music writing. and auditory perception). This may cause my child to feel nervous about making mistakes and feel tired from sitting at the piano and desk. I have received assurance from the research assistant that every effort will be made to minimize these risks. Regarding potential nervousness, the research assistant will encourage my child to do their best and explain to my child there is no incorrect way to play, read, or write for these music games, ensuring to refer to them as games always. Regarding tiredness, the research assistant will tell my child they can take a break or stop the music games if they are feeling tired. During the games session, there will be a scheduled break. My child's participation in the interview may cause my child to feel nervous about answering the questions and tired from sitting down during the interview. Regarding

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potential nervousness, the principal investigator will encourage my child to do their best, and explain to my child there is no incorrect way to answer the questions. Regarding tiredness, the principal investigator will tell my child they can take a break or stop the interview if they are feeling tired.

Benefits: My child's participation and my participation in this study will benefit music researchers who are studying dysmusia (musical dyslexia) and music reading development in children. My child's participation contributes to our understanding of the relationship between music reading, music writing, and auditory perception, which are thought to be related in cases of dysmusia. The results of our study will be able to shape how music reading is taught among the broader piano teaching community.

Confidentiality and anonymity: I have received assurance from the principal investigator that the information I will share, and the data from my child's participation and my participation will remain strictly confidential. I understand that the contents will be used only for exploring a case of a young piano student with dyslexia. My and my child's confidentiality will be protected. The research assistant will provide my child with a randomized numerical tag at the beginning of the first session, and this number will be attached to my child's data rather than their name or other personal identifiers. In the publication of case study data, the case will be described using a pseudonym.
Anonymity will be protected in the following manner. The principal investigator will store the data in a secure, password protected computer drive at the Piano Pedagogy Research Laboratory. Only the principal investigator and research supervisor will have access to the data files. My child's data from video recordings will be renamed according to your child's numerical identifier. Paper materials will only have your child's numerical identifier on them and will be stored in a secure box within the Piano Pedagogy Research Laboratory. My child's identity will not be revealed in publications.

Conservation of data: The data collected (intake questionnaire, video recording, Musical Instrument Digital Interface (MIDI) and paper materials) will be kept in a secure manner at the Piano Pedagogy Research Laboratory. The digital materials (video recording and MIDI) will be stored in a secure, password protected computer drive at the Piano Pedagogy Research Laboratory at the University of Ottawa. The hard copies (intake questionnaires, paper materials), will also be kept at the Piano Pedagogy Research Laboratory. It will be retained for five years following completion of the study.

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Voluntary Participation: My child is under no obligation to participate, and if they choose to participate, they can withdraw from the study at any time and/or refuse to answer any questions without suffering any negative consequences (nervousness, fatigue). If my child chooses to withdraw, all data gathered until the time of withdrawal will be deleted.

Acceptance: I, ________________________, consent that my child can participate in the above research study conducted by Meganne Woronchak of the School of Human Kinetics, Faculty of Health Sciences, and Piano Pedagogy Research Laboratory, University of Ottawa, supervised by Dr. Gilles Comeau and assisted by Mikael Swirp.

If I have any questions about the study, I may contact Meganne Woronchak or her thesis supervisor Dr. Gilles Comeau.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5
Tel.: (613) 562-5387
Email: ethics@uottawa.ca

There are two copies of the consent form, one of which is mine to keep.

Parent's signature: Date:

Principal Investigator's signature: Date:

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Appendix 8D: Survey of Musical Interests

Parent's or Guardian's Questionnaire

Piano Pedagogy Research Laboratory

University of Ottawa

GENERAL INFORMATION

Parent’s or Guardian’s Name	
Child’s Name	
Instrument Teacher’s Name	
Date	

This form is to be filled out by the child’s parent(s) or guardian(s).

NOTE

Rest assured that this information will remain strictly confidential. Only the research team will have access to this information. Only group data (e.g., group averages) will be made public when we present the results of this study in scientific conferences or similar contexts.

PLEASE CHECK THE BOX NEXT TO, OR ENTER YOUR RESPONSES TO THE QUESTIONS PRESENTED BELOW.

SECTION 1: DEMOGRAPHIC INFORMATION

	QUESTIONS	YOUR RESPONSES
1	What is your child's gender:	
2	Age of your child:	
3	Birth date of your child (month and year)	
4	Ethnic Background of your child's mother (or adoptive mother if child adopted) *Please check all that apply*	☐ European (e.g., white) ☐ Asian (e.g., Chinese, Japanese, Korean, South-east Asian) ☐ East Indian, Pakistani ☐ African-American/Black/Caribbean ☐ Hispanic ☐ Middle-Eastern ☐ First Nations, Métis, Inuit ☐ Other: _________
5	Ethnic Background of your child's father (or adoptive father if child adopted) *Please check all that apply*	☐ European (e.g., white) ☐ Asian (e.g., Chinese, Japanese, Korean, South-east Asian) ☐ East Indian, Pakistani ☐ African-American/Black/Caribbean ☐ Hispanic ☐ Middle-Eastern ☐ First Nations, Métis, Inuit ☐ Other: _________
6	Ethnic Background of your child's instrument teacher *Please check all that apply*	☐ European (e.g., white) ☐ Asian (e.g., Chinese, Japanese, Korean, South-east Asian) ☐ East Indian, Pakistani ☐ African-American/Black/Caribbean ☐ Hispanic ☐ Middle-Eastern ☐ First Nations, Métis, Inuit ☐ Other: _________

7	What is the occupation and highest academic degree of the mother?	Occupation: ______________________ ☐ High school diploma ☐ College diploma ☐ Bachelor's ☐ Master's ☐ PhD ☐ Other: _________
8	What is the occupation and highest academic degree of the father?	Occupation: ______________________ ☐ High school diploma ☐ College diploma ☐ Bachelor's ☐ Master's ☐ PhD ☐ Other: _________
9	How would you rate your child's overall academic abilities in school?	☐ Higher than most students ☐ Higher than average ☐ About average ☐ Lower than average ☐ Lower than most students
10	How would you qualify the reading skills of your child?	☐ Excellent ☐ Good ☐ Average ☐ Poor ☐ Very poor
11	Has your child been diagnosed with dyslexia?	☐ Yes ☐ No Any additional comments:
12	What other extra-curricular activities is your child involved in?	

SECTION 2: CHILD'S MUSICAL HISTORY

11	At what age did your child begin taking instrument lessons? (years and months)	
12	Which music book(s) did your child use when beginning instrument lessons? *You can ask your child.*	
13	Which music book(s) is your child currently using? *You can ask your child.*	
14	Which were the last 3 pieces that your child has worked on? *You can ask your child.*	
15	What is your child's current level?	Preparatory/pre-grade: _______ Grade level: _______ Suzuki book: _______ Other: _____________________________
16	Has your child taken any instrument exams so far? *If not, skip to question #21*	☐ Yes ☐ No
17	If so, which type of exam has your child taken?	☐ Royal Conservatory of Music exam ☐ Conservatory Canada Piano exam ☐ Other: ___________________________
18	What is the grade level of your child's most recent instrument exam?	

19	What is the date (month and year) of your child’s most recent instrument exam?	
20	What was the result of this exam?	
21	Has your child ever participated in *group* music lessons? *If not, skip to question #25*	☐ Yes ☐ No
22	If so, with which method?	☐ Yamaha ☐ Music for Young Children ☐ Suzuki ☐ Other ________________
23	How many years was your child enrolled in group music lessons?	
24	If your child is no longer in group lessons, What was your reason for leaving them?	☐ Scheduling conflict ☐ Student became too advanced to continue in a group lesson format, thus the teacher recommended private lessons ☐ Streaming issue - the class was too fast/slow for my child's pace ☐ My child is better suited to private lesson format ☐ Other (please specify): ______________
25	In your opinion, how long will your child continue to take instrument lessons?	☐ Intends to stop soon ☐ Until the end of elementary school ☐ Until the end of high school ☐ Will continue after the end of high school
26	In your opinion, do you think your child will continue to play the instrument (somewhat regularly) as an adult?	☐ Absolutely ☐ Most likely ☐ Probably ☐ Maybe ☐ Not likely
27	How would you rate your child’s instrument playing abilities?	☐ Higher than most students ☐ Higher than average ☐ About average ☐ Lower than average ☐ Lower than most students

SECTION 3: FAMILY MUSICAL HISTORY

28	Has the child's mother ever taken music lessons, for any kind of instrument? *If not, skip to question #32*	☐ Yes ☐ No If yes:
29	**1st Instrument**	• Which instrument? _______________ • Approximately how many years?____ • At what age did she start lessons?___ • At what age did she stop lessons?___ • Does she still play today? Yes No
30	**2nd instrument**	• Which instrument? _______________ • Approximately how many years? ____ • At what age did she start lessons?___ • At what age did she stop lessons?___ • Does she still play today? Yes No
31	**3rd instrument**	• Which instrument? _______________ • Approximately how many years? ____ • At what age did she start lessons?___ • At what age did she stop lessons?___ • Does she still play today? Yes No
32	Has the child's father ever taken music lessons, for any kind of instrument? *If not, skip to question #36*	☐ Yes ☐ No If yes:
33	**1st Instrument**	• Which instrument? _______________ • Approximately how many years?___ • At what age did he start lessons?___ • At what age did he stop lessons?___ • Does she still play today? Yes No
34	**2nd instrument**	• Which instrument? _______________ • Approximately how many years? ____ • At what age did he start lessons?___ • At what age did he stop lessons?___ • Does she still play today? Yes No
35	**3rd instrument**	• Which instrument? _______________ • Approximately how many years? ____ • At what age did he start lessons?___ • At what age did he stop lessons?___

		• Does she still play today? Yes No
36	Does your child have any siblings who are taking music lessons?	☐ No siblings Sibling 1: age____________ ☐ Too young to take music lessons ☐ Music not a priority for this child ☐ Started but stopped ☐ Has been taking music lessons for _____ years ☐ Which instrument(s)? __________ Sibling 2: age____________ ☐ Too young to take music lessons ☐ Music not a priority for this child ☐ Started but stopped ☐ Has been taking music lessons for _____ years ☐ Which instrument(s)? __________ Sibling 3: age____________ ☐ Too young to take music lessons ☐ Music not a priority for this child ☐ Started but stopped ☐ Has been taking music lessons for _____ years ☐ Which instrument(s)? __________ Sibling 4: age____________ ☐ Too young to take music lessons ☐ Music not a priority for this child ☐ Started but stopped ☐ Has been taking music lessons for _____ years ☐ Which instrument(s)? __________

SECTION 4: CHILD'S INSTRUMENT LESSONS & RECITALS

37	How often do you (or your spouse) sit in on your child's instrument lesson?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once or twice each month) ☐ Often (several times a month) ☐ Always (every week)
38	If you (or your spouse) sit in on your child's instrument lesson, it is because	☐ I was invited by the teacher ☐ It was my own decision
39	If you (or your spouse) never sit in on your child's instrument lesson, it is because	☐ Teacher would not allow it ☐ I never thought about attending my child's lesson ☐ I do not have time, scheduling conflict ☐ I'm not sure I would be very helpful ☐ I have no interest in attending the lesson
40	If you (or your spouse) never sit in at your child's instrument lesson, how often do you contact the teacher (in person, phone calls or e-mails) for information on your child's progress?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once or twice each month) ☐ Often (several times a month) ☐ Always (every week)
41	If you (or your spouse) sit in at your child's instrument lessons, to what degree do you focus on what is going on in the lesson?	☐ Focus entirely on something else ☐ Focus largely on something else ☐ Focus partly on something else and partly on the lesson ☐ Focus largely on the lesson ☐ Focus entirely on the lesson ☐ Does not apply as I never attend my child's lesson
42	Does the child's mother attend the child's concerts/recitals?	☐ Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐ If not, please explain why:
43	Does the child's father attend the child's concerts/recitals?	☐ Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐ If not, please explain why: ____________________________

SECTION 5: CHILD'S INSTRUMENT PRACTICE

44	At home, how often does your child have access to a quiet and conducive space for practicing?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once or twice each month) ☐ Often (several times a month) ☐ Always (every week)
45	This year, on average, how many days a week does your child practice the instrument?	______ days per week.
46	This year, on average, how long is each practice session?	
47	Practice history: on average, how many days a week was your child practicing the instrument?	1 year ago _________________ 2 years ago ________________ 3 years ago ________________
48	Practice history: on average, how long was each practice session?	1 year ago _________________ 2 years ago ________________ 3 years ago ________________
49	How often do you (or your spouse) help your child with their instrument practice?	☐ Never ☐ Seldom (once or twice a week) ☐ Sometimes (for about half of the weekly practice) ☐ Often (more than half of the weekly practice) ☐ Always
50	Which of the following best describes you (or your spouse) during your child's instrument practice?	☐ I am not really involved ☐ I listen to my child's practice from a distance so I know what is going on ☐ I provide feedback when I hear something wrong or something well played ☐ I work with my child during his/her practice
51	How often do you (or your spouse) praise your child for home practices?	☐ Never ☐ Seldom (once or twice a week) ☐ Sometimes (for about half of the weekly practice)

		☐ Often (more than half of the weekly practice) ☐ Always
52	How often do you (or your spouse) offer your child material rewards or privileges for home practices?	☐ Never ☐ Seldom (once or twice a week) ☐ Sometimes (for about half of the weekly practice) ☐ Often (more than half of the weekly practice) ☐ Always
53	How often do you (or your spouse) praise your child for achievements or milestones in music? *(e.g., performance at a concert, competition, exam, completing a certain level)*	☐ Never ☐ Seldom (a little less than half the time) ☐ Sometimes (half the time) ☐ Often (more than half the time) ☐ Always
54	How often do you (or your spouse) offer your child material rewards or privileges for achievements or milestones in music?	☐ Never ☐ Seldom (a little less than half the time) ☐ Sometimes (half the time) ☐ Often (more than half the time) ☐ Always
55	If you (or your spouse) reward your child for practicing or for achievement, what sort of rewards do you provide?	

SECTION 6: OTHER MUSICAL EXPERIENCES

56	How often does your child attend summer music camps?	☐ Never ☐ Seldom ☐ Sometimes ☐ Often (almost every summer) ☐ Always (every summer)
57	How often does your child attend master classes or workshops?	☐ Never ☐ Seldom (less than once a year) ☐ Sometimes (once a year) ☐ Often (more than once a year) ☐ Always (4 times and more per year)
58	How often does your child participate in any kind of collective music-making, such as duets, small/large ensemble, etc.?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once a month) ☐ Often (a few times a month) ☐ Always (every week)

59	How often does your child participate in any kind of informal performances? *(e.g. "family and friends", playing in retirement homes, etc.)*	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once a month) ☐ Often (a few times a month) ☐ Always (every week)
60	How often do you (or your spouse) listen to CLASSICAL music together with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (a few days a month) ☐ Often (a few days a week) ☐ Always (every day)
61	How often do you (or your spouse) listen to JAZZ music together with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (a few days a month) ☐ Often (a few days a week) ☐ Always (every day)
62	How often do you (or your spouse) listen to POP music together with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (a few days a month) ☐ Often (a few days a week) ☐ Always (every day)
63	How often do you (or your spouse) listen to COUNTRY OR WORLD music together with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (a few days a month) ☐ Often (a few days a week) ☐ Always (every day)
64	How often do you (or your spouse) attend professional classical concerts with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once a month) ☐ Often (a few times a month) ☐ Always (every week)
65	How often do you (or your spouse) attend other concerts with your child?	☐ Never ☐ Seldom (a few times a year) ☐ Sometimes (once a month) ☐ Often (a few times a month) ☐ Always (every week)
66	If so, what kind(s) of concert(s)?	

SECTION 7: PARENTS' OPINION

67	In your opinion, when your child does well in music, it is because:	☐ My child is talented ☐ My child practices hard ☐ My child is talented and practices hard ☐ My child is lucky
68	In your opinion, to succeed in music, your child needs:	☐ To work harder and practice more than most students ☐ To work and practice about the same as most students ☐ To work less and practice less than most students
69	In your opinion, musical ability is:	☐ Something we are born with ☐ Something we can develop by working on it ☐ Both of the above

THANK YOU FOR TAKING THE TIME TO FILL OUT THIS FORM

Our goal is to promote a research-based approach to piano pedagogy

and apply this approach to the continuous improvement of piano teaching

Appendix 8E: Music Reading Tests

Description

Description of the music reading test battery

Test	Description	Trials
Note Naming		
Keyboard presentation	Notes are indicated by a red dot on a graphic of a one-octave keyboard (C to B). Participant says the letter name of each note.	3 practice trials followed by 10 test trials. Stimuli appears for 1 second, with 2 seconds between each stimuli.
Staff presentation	Single notes appear in treble clef (test 1), and bass clef (test 2). Participant says the letter name of each note	3 practice trials followed by 14 test trials for each of the two tests. Stimuli appears for 1 second, with 2 seconds between each stimuli.
Note playing		
Single notes*	Single notes appear in treble clef middle C position (test 1) and G4 position (test 2). Participant's hand is guided to correct location on the keyboard and plays each note as they appear.	3 practice trials followed by 8 test trials for each of the two tests. Stimuli appears for 1 second, with 2 seconds between each stimuli.
Broken intervals	Two notes appear in broken form in treble clef middle C position (test 1) and G4 position (test 2). Participant's hand is guided to correct location on the keyboard and plays each note pair as they appear.	2 practice trials followed by 15 test trials for each of the two tests. Stimuli appears for 2 seconds, with 2 seconds between each stimuli.
Solid intervals	Two notes appear in solid form in treble clef middle C position (test 1) and G4 position (test 2). Participant's hand is guided to correct location on the keyboard and plays each note pair as they appear.	2 practice trials followed by 15 test trials for each of the two tests. Stimuli appears for 2 seconds, with 2 seconds between each stimuli.
3-Note Patterns	Three notes appear in broken form in the treble clef middle C position (test 1) and G4 position (test 2). Some of the note groups were patterns (scalar or notes of the root triad), while others did not form an obvious pattern.	2 practice trials followed by 21 test trials for each of the two tests. Stimuli appears for 2 seconds, with 2 seconds between each stimuli.

* Not included in the proposed screening tool, but the stimuli are used in the copying and dictation tests.

In addition to the above tests, participants perform the B Series of Mary Gardiner's Levelled Pieces (up to 11 excerpts). The first test is to sight-read through a simple 1-line excerpt. The participant is first told where to situate his/her hands at the keyboard, then asked to play through the short piece of music immediately after it is presented to them. The second test is similar, although slightly more difficult. Tests 3-11 are directed towards late beginner to advanced players, and participants are instructed to independently find their starting hand positions. These tests give an indication of their sight-reading level. See the excerpts for these tests below.

Protocols

Protocol for Note Naming/Note Playing Tests

Equipment Checklist

- Video camera
- Tripod
- Piano keyboard
- Computer (laptop) with sequence/pattern recognition program loaded
    - This will contain 4 subtests
        a. Naming Notes (Keyboard Presentation)
            - 3 practice, 10 trials
        b. Naming Notes (Staff Presentation – treble clef)
            - 3 practice, 14 trials
        c. Naming Notes (Staff Presentation – bass clef)
            - 3 practice, 14 trials
        d. Playing notes (Treble C position)
            - 3 practice, 8 trials
        e. Playing notes (Treble G position)
            - 3 practice, 8 trials
- Laptop with mouse
- Log sheet for tracking responses (oral only)

Protocol

Naming Condition Keyboard

1. Place video camera next to participant. Ensure that the keyboard and the computer screen are in view. Turn on video camera.
2. Have participant show ID to camera.
3. Write down participant's ID, time, etc in logbook.
4. Sit participant at piano. Stand to the side of the participant to not block camera.
5. Give a brief explanation of the first condition saying: "*You are going to see a piano come up on the screen and a red dot will land on the note. As soon as you know the name of the note, tell me. After you tell me, the next one will appear until the video ends. Do you understand?"*

6. Make sure the computer window is maximized. Press the “1” key, to begin the program and expose the first stimuli. The remainder of the stimuli will continue to appear automatically. Keep note of all of the participant’s responses on your log sheet (all letters that they say).

Naming Condition Staff

1. *Good work. This time, instead of a piano, notes will be shown on the spaces and lines of the treble clef. Do you know where the treble clef is on the piano?*
   If no, explain and demonstrate that it is everything higher than middle C. If yes, continue.
2. *Just like before, I want you to try your best to tell me the name of the note. The notes will keep going, so if you know the answer, tell me quick before the next one appears. If you really don’t know, you can tell me that you don’t know. And that’s OK. Do you understand? Let’s try a few practices.*
3. Press the “1” key, to begin the program and expose the first stimuli. 3 practice stimuli will appear in a row.
4. *Do you see how fast they went? The rest of the notes are going to be just that fast. Remember, just try your best.*
5. Press “2” to continue the program. The remainder of the stimuli will continue to appear automatically. Keep note of all of the participant’s responses on your log sheet (all letters that they say).
6. *Good work. Now, instead of treble clef notes will be shown on the spaces and lines of the bass clef. Do you know where the bass clef is on the piano?* If no, explain and demonstrate that it is everything lower than middle C. If yes, continue.
7. Repeat steps 2-5 with bass clef test.

Playing Condition-Test 1…RH C Position

1. *This time, we are going to play notes instead of naming them. Can I get you to put your RH thumb on middle C?* If the participant has any trouble finding the proper hand position, give some assistance.
2. *This time, as soon as you see the note, try to play that note on the piano as soon as it appears on the screen. The notes won’t go past where your fingers are. Do you understand what to do?*
3. Say: “*Great, now can you spread out your fingers so that each finger has its own key? Alright, now more notes are going to appear on the screen. Can you play them for me as soon as you see them appear? Are you ready?”*
4. Press the “1” key, to begin the program and expose the first stimuli. 3 practice stimuli will appear in a row.
5. *Do you see how fast they went? The rest of the notes are going to be just that fast. Remember, just try your best.*
6. Press “2” to continue the program. The remainder of the stimuli will continue to appear automatically. Keep note of all of the participant’s responses on your log sheet (all letters that they say).

Playing Condition-Test 2…. RH G Position

1. *This time, we are going to play notes instead of naming them. Can I get you to put your RH thumb on the G above middle C?* If the participant has any trouble finding the proper hand position, give some assistance.
   2. *Again, as soon as you see the note, try to play that note on the piano as soon as it appears on the screen. The notes won't go past where your fingers are. Do you understand what to do?*
   3. Say: "*Great, now can you spread out your fingers so that each finger has its own key? Alright, now more notes are going to appear on the screen. Can you play them for me as soon as you see them appear? Are you ready?"*
   4. Press the "1" key, to begin the program and expose the first stimuli. 3 practice stimuli will appear in a row.
   5. *Do you see how fast they went? The rest of the notes are going to be just that fast. Remember, just try your best.*
   6. Press "2" to continue the program. The remainder of the stimuli will continue to appear automatically. Keep note of all of the participant's responses on your log sheet (all letters that they say).

Appendix 8F: Music Writing Tests

Description

Description for both Copying and Dictation Tests:

- Novel music writing tests concerning copying and dictation that were constructed using stimuli from the Piano Lab Music Reading Tests
- To explore the nature of writing difficulties as an indicator of dysmusia, both at the visual level (copying) as well as aural and visual (dictation):
- Are responses correct, partially correct, or incorrect?
- Do responses that are partially correct have reversed notes, neighbour notes, and/or the correct contour?
- Are responses "messy" (e.g., noteheads not quite on the line or space, long or short stem)?

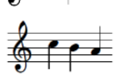
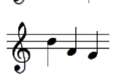
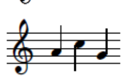
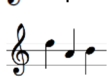
Equipment for both Copying and Dictation Tests:

- Booklet with staff paper labelled according to stimuli number, printed landscape
- Sharpened pencils (ideally without eraser)
- Computer with PowerPoint or PDF reader (specific to copying)
- Mouse (specific to copying)

Copying Test

Copying Test Stimuli

Trial			Source
P	C4		Single note playing, C position, T5
1	F4		Single note playing, C position, T1
2	D4		Single note playing, C position, T2
3	G4		Single note playing, C position, T3
4	E4		Single note playing, C position, T4
5	C4		Single note playing, C position, T5
6	G4		Single note playing, C position, T6
7	D4		Single note playing, C position, T7
8	F4		Single note playing, C position, T8

9	B4		Single note playing, G position, T1
10	G4		Single note playing, G position, T2
11	C5		Single note playing, G position, T3
12	A4		Single note playing, G position, T4
13	C5		Single note playing, G position, T5
14	G4		Single note playing, G position, T6
15	D5		Single note playing, G position, T7
16	B4		Single note playing, G position, T8
17	F4-D4-E4		3-note patterns, C position, T1
18	C4-E4-G4		3-note patterns, C position, T2
19	G4-D4-E4		3-note patterns, C position, T3
20	C4-G4-E4		3-note patterns, C position, T4
21	C4-D4-G4		3-note patterns, C position, T5
22	D4-F4-C4		3-note patterns, C position , T6
23	E4-G4-C4		3-note patterns, C position, T7
24	E4-C4-F4		3-note patterns, C position, T8
25	B4-A4-C5		3-note patterns, G position, T1
26	G4-B4-D5		3-note patterns, G position, T2
27	C5-B4-A4		3-note patterns, G position, T3
28	G4-D5-B4		3-note patterns, G position, T4
29	D5-A4-G4		3-note patterns, G position, T5
30	A4-C5-G4		3-note patterns, G position, T6
31	D5-A4-B4		3-note patterns, G position, T7
32	A4-B4-C5		3-note patterns, G position, T8

Note: The stimuli appear in the same order as they do in the music reading tests

Protocol for copying test:

1. Give participant a printed booklet (landscape) to write their responses.
2. Load slide show. Slide 1, **Music copying**, Text on slide: ***Please click "Slideshow" then "From beginning".***
3. Read text on slide 2 aloud to participant: ***On each slide, you will see notes on the treble clef. You will copy the notes that you see. Here is a practice [reveal slide with middle C on the treble clef.]***
4. ***Great work! Now, you will copy more notes until I say we are done. The sheets to write on will always be top page-bottom page in your booklet [demonstrate.] I will let you turn the pages. When you are finished writing the notes, tell me and I will show you the next one. If you think you have made a mistake, cross it out with an X [demonstrate] and try again. Try to copy the notes as fast you can, although there is no timer.***
5. Continue until the slide that says "Congratulations!"

Dictation Test

Dictation Test Stimuli

Single note dictation, treble clef

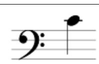
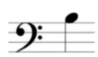
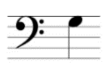
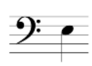
	Trial		Source: Treble Clef Recognition
P	C4 (middle C)		T13
1	G4		T1
2	C5 (or C4)	 or 	T2 / 13
3	D4		T5
4	A4		T7
5	B4		T11

2-note dictation, treble clef

	Trial		Source: 2-note intervals
P	C4-E4		C position 6
1	F4-D4		C position 15

2	G4-D4		C position 15
3	G4-B4		G position 12
4	D5-A4		G position 13
5	G4-C5		G position 2

Single-note dictation, bass clef

Trial			Source: Bass Clef Recognition
P	C4 (middle C)		Bass T4
1	A3		T9
2	F3		T1
3	B3		T7
4	G3		T6
5	E3		T12

Ensure to know beforehand

- Which note naming system does the participant use? You will know either by administering the note naming tests first, or by asking them to name some notes aloud for you.
- Examples: Arabic letters (A through G), French solfege (do through si), and English solfege (do through ti)
- "Translate" the instructions as needed to accommodate how the participants understand note names.

Protocol for dictation test

1. Give participant a printed booklet (landscape) to write their responses.
2. Instruct: ***For this game, you will write down notes that you hear on the staff paper in front of you. Please use quarter notes. I will tell you which notes to write and will repeat them if***

you ask me to. Now, the notes are in the treble clef. Please use quarter notes*. *This game will start with a practice. Do you understand?

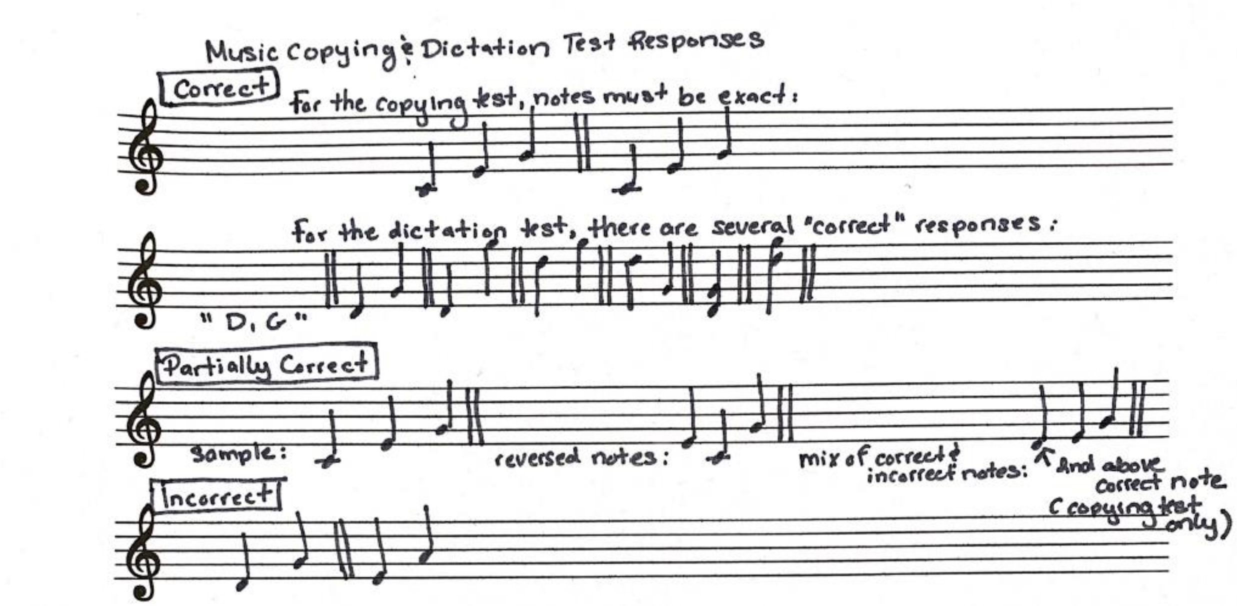
3. If yes, flip page to **"Practice-1 note, treble clef" (page 1)**
4. Instruct: ***Please write "middle C" and let me know when you have finished.***
5. Ask: ***Do you have any questions?***
6. Instruct: ***We are about to start the game. This time, you will write the responses on the top pages and then the bottom pages of your booklet [demonstrate]. If you think you made a mistake, simply cross out the notes and try again [demonstrate].***
7. Help participant turn to page labelled "G 1 – 1." Say: ***G***. [Note: If participant asks which note if there are two possible options (e.g., middle C or high C), tell them: ***Whichever you'd like.***]
8. Repeat step 8 for next 4 trials: C, D, A, B
9. Instruct: ***Great! Now we are going to play a similar game, this time with two notes to write at a time in the treble clef instead of one. Let's practice***. Help participant turn to page labelled, **"Practice-2 notes, treble clef."** ***Please write C-E and let me know when you are finished.*** After, ask: ***Do you have any questions?***
10. Help participant turn to page labelled **G2 – 1**. Say: ***F-D.*** [Note: If participant asks which note if there are two possible options (e.g., middle C or high C), tell them: ***Whichever you'd like.***]
11. Repeat step 11 for next 4 trials: G-D, G-B, D-A, G-C
12. Instruct: ***Great! Now we are going to play a similar game, this time with one note to write at a time in the baff clef instead of the treble clef. Let's practice.*** Help participant turn to page labelled, **"Practice-1 note, bass clef."** ***Please write, middle C, and let me know when you have finished***. Ask: ***Do you have any questions?***
13. Help participant turn to page labelled **G3 – 1**. Say: ***A.*** Note: If participant asks which note if there are two possible options (e.g., middle C or low C), tell them: ***Whichever you'd like***].
14. Repeat step 13 for next 4 trials: F, B, G, E.

Scoring

Level 1: Correct, Partially Correct, or Incorrect Responses

Responses are marked as correct, partially correct, or incorrect based on the placement of the notehead. As visualized in figure 2, if a correct response is C, E, G, then a partially correct response would contain either the correct notes but in reverse order, or a mixture of correct and incorrect notes. A partially correct response receives a score of 0.5. If a response contains no correct notes, it is marked as incorrect and receives 0 points. In the copying test, if a participant writes an incorrect note, we include the interval (e.g., a D mistaken for C would be a "2nd"). We do not include this component in the dictation test, because we do not know in which octave a participant is thinking (e.g., if the trial stimulus is "D, G" in the treble clef, a participant has four possible correct responses).

Level 1: Correct, Partially Correct, or Incorrect Responses



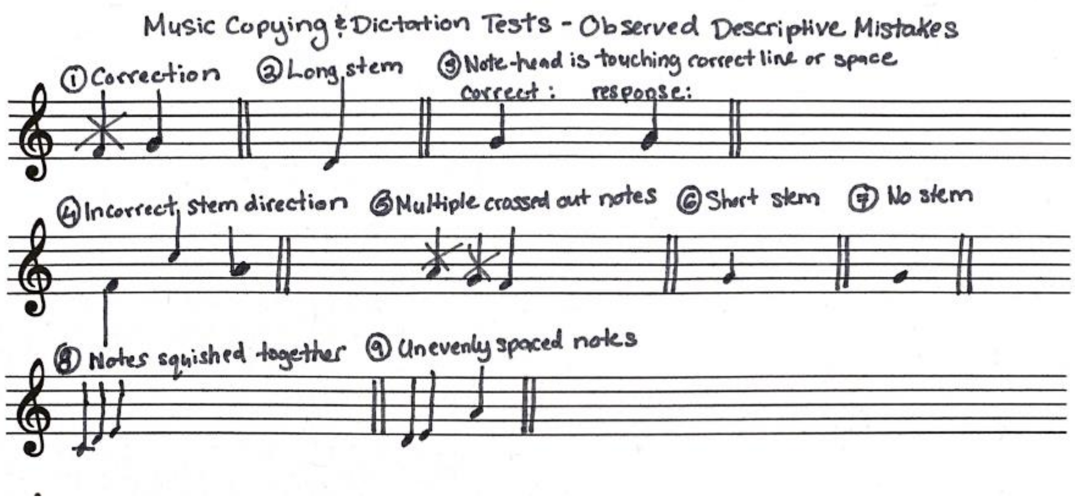
Level 2: Observed Descriptive Mistakes in Copying and Dictation Tests

Observed descriptive mistakes can be part of both correct, partially correct, and incorrect responses to stimuli (see figure 3). For example, if a student copied the G notehead correctly after crossing out an incorrect F note, the response was scored at level 1 as correct, but the correction necessitates a deduction at level 2. Each deduction is 0.25 points. See table 10 for scoring.

Writing Test Scoring

Level 1 Score	**Level 2 Score**
Correct: 1 point	1 mistake: 0. 75 points
	2 mistakes: 0.5 points
	3 mistakes: 0.25 points
	4 mistakes: 0 points
Partially Correct: 0.5 points	1 mistake: 0.24 points
	2 mistakes: 0 points
Incorrect: 0 points	0 points

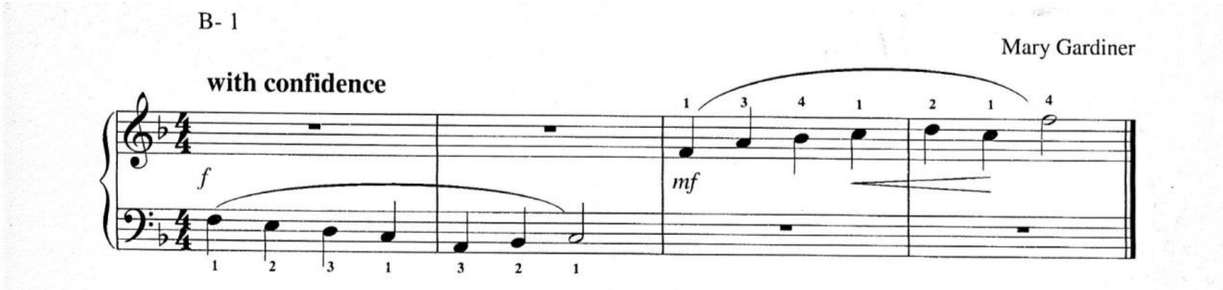
Level 2: Observed Descriptive Mistakes in Copying and Dictation Tests


Music Copying & Dictation Tests - Observed Descriptive Mistakes
① Correction
② Long stem
③ Note-head is touching correct line or space
correct:
response:
④ Incorrect stem direction
⑤ Multiple crossed out notes
⑥ Short stem
⑦ No stem
⑧ Notes squished together
⑨ Unevenly spaced notes

Appendix 8G: Music Sight-Reading Test

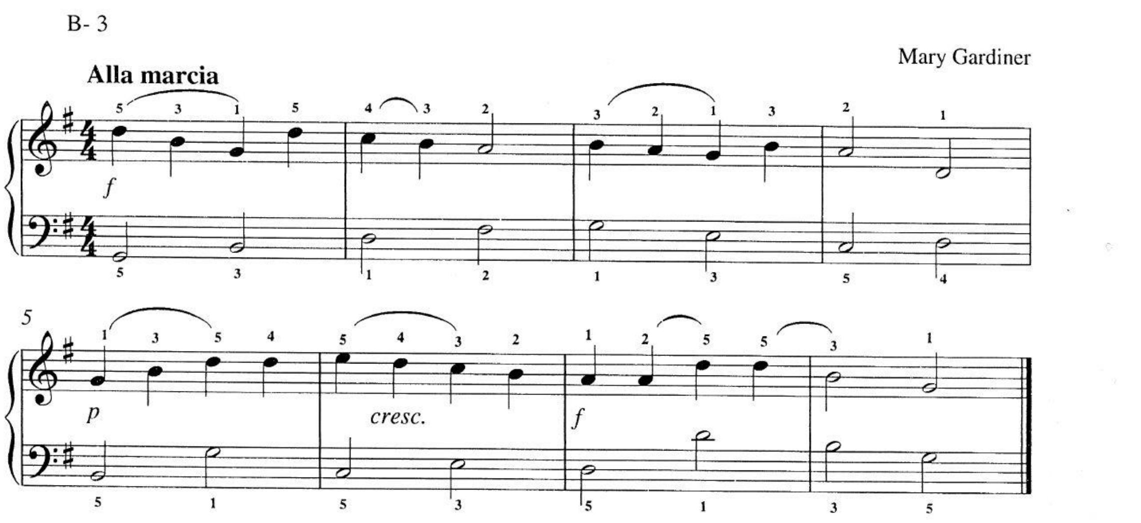
Pieces

B1

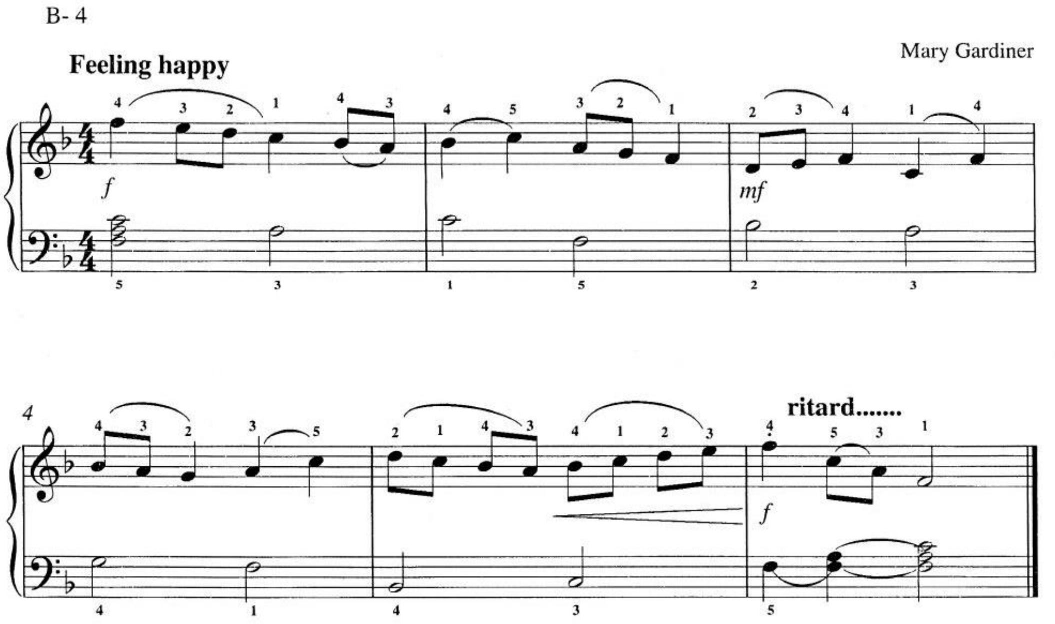


B2

B3



B4


B- 4
Feeling happy
Mary Gardiner
f
mf
ritard.......
f

B5


B- 5
Vif
Mary Gardiner
mf
f
p
mf
f

B6


B - 6
Mary Gardiner
tristement
mp
poco cresc.
poco rall

B7


B - 7
Mary Gardiner
Lento espressivo
mp
poco a poco crescendo
f
molto rit.

B8

Protocol

Protocol for Sight Reading

Equipment Checklist

- Video camera
- Tripod
- MIDI Piano keyboard
- MIDI interface
- Music stand
- Hard Copy of A1, B1 and B2 Sight reading material
- Guide with finger position
- Clipboard
- Logbook

Protocol

7. Place video camera next to participant. Ensure that the keyboard and the computer screen are in view. Turn on video camera.
8. Have participant show ID to camera.
9. Write down participant’s ID, time, etc in logbook.

10. Sit participant at piano. Stand to the left of the participant to not block camera.
11. Give a brief explanation of the first condition saying: "*When you are ready, I am going to show you a piece of music on the screen. I want you to play it for me as best as you can.*
12. Direct the participant to place both of their thumbs on Middle C, and tell them *"Your hands will start here, but you may have to move them when you play the piece. As soon you see the music, start playing right away. Do you understand what to do?"*
13. Press "1" on laptop to start MIDI recording. Enter "participant id#"
14. Place piece B1 in front of the participant and have participant play through the piece.
15. *Now we are going to sight read a piece. I want you to play it for me as best as you can."*
16. Move the student into the proper hand position (LH thumb on F below Middle C and RH thumb on F above Middle C). "*Your hands will start here, but you may have to move them when you play the piece. As soon you see the music, start playing right away. Do you understand what to do?"* Place sight-reading material in front of the participant. Have participant play through the second piece.
17. If successful, then continue to the second piece (B2). *Repeat step 11. Say, "Your hand position is LH 5th finger on G below Middle C and RH 5th finger on D5."*
18. If successful, continue onto third piece (B3). Say, "Now, you must find your hand position. Start playing as soon as you can."
19. If successful, keep repeating until participant makes several mistakes within several bars of a piece.
20. Press 2 on the keyboard to end this section.

End of experiment

Appendix 8H: Piano Lab Sight-Reading Scale

Piano Pedagogy Lab Reading Scale

for piano[22]

[22] The sight-reading scale is the property of the Piano Pedagogy Research Laboratory. Please contact the Piano Pedagogy Research Laboratory for more information.

Appendix 8I: Handedness

Participant #:
Administrator:

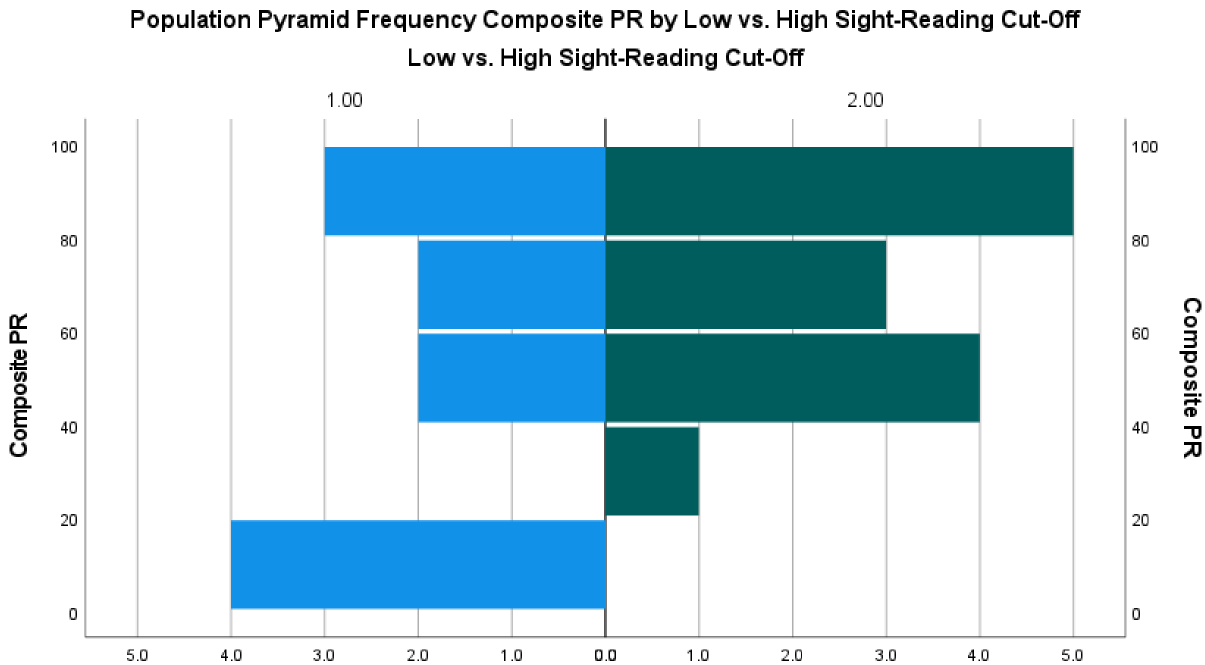
Administrator: "Pretend you are ______ (*insert activity*)." *Circle R (for right), L (for left), or E (for either)*.			
Writing/ drawing	L	R	E
Throwing a ball	L	R	E
Using scissors	L	R	E
Using a toothbrush	L	R	E

Appendix 8J: Complete Participant Demographic Information

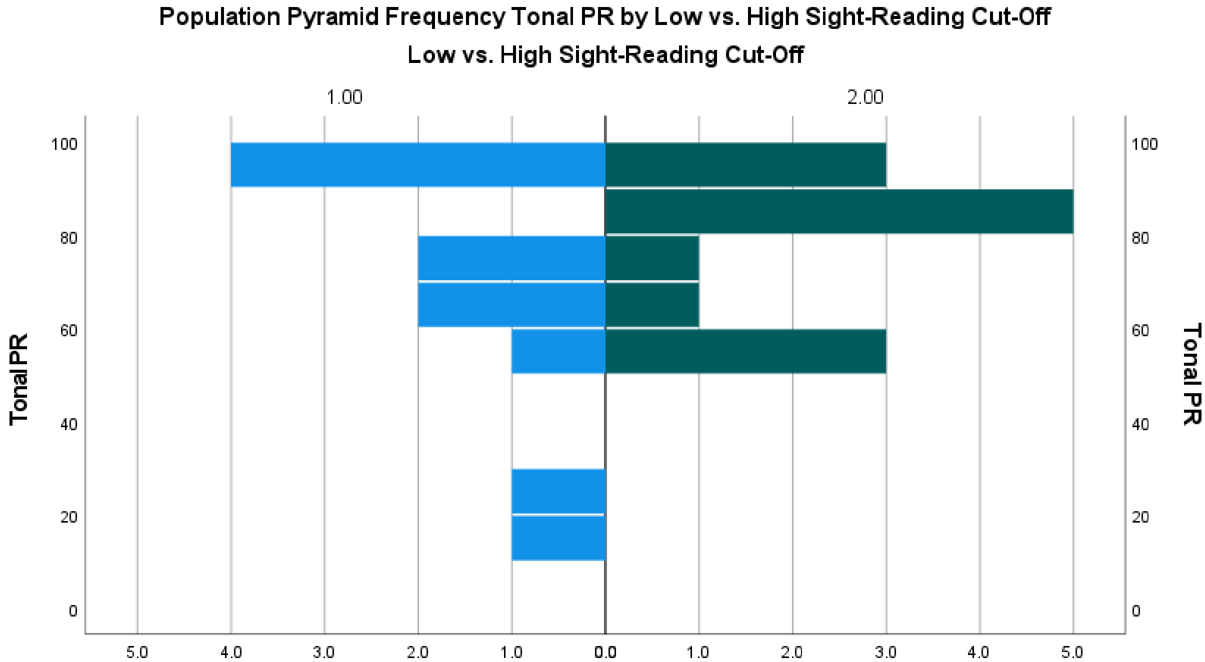
Participant	**Gender**	**Age**	**Level**	**No. years reading music**	**No. years in lessons**	**Preferred writing hand**	**Music learning method**
A 599	M	10.3	Beg.	1.5	2	R	Suzuki
B 600	F	15.6	Int-Adv.	10	10	R	RCM and Yamaha
C 601	F	12.8	Int-Adv.	4	4	R	RCM and Yamaha
D 602	F	13.9	Int-Adv.	8	8	R	RCM and Yamaha
E 603	M	15.1	Beg.	2	5	R	Alfred’s Basic
F 604	M	10.1	Beg.	3	4	L	Piano Adventures
G 605	M	10.9	Beg.	1	4.	R	Suzuki
H 606	M	10.4	Int-Adv.	3	6.5	R	Con. Canada
I 607	M	12.9	Int-Adv.	5	5	R	RCM
J 608	F	14.6	Int-Adv.	6	7.5	R	RCM
K 609	F	13.3	Int-Adv.	5	6	R	Con. Canada
L 610	F	8.9	Beg.	3	4	R	Yamaha
M 611	F	11.8	Beg.	3	3	R	Yamaha
N 612	M	12.4	Beg.	7.5	7.5	L	L’école de musique Vincent-d ‘Indy
O 613	M	14.4	Int-Adv.	7	8.5	R	RCM
P 614	F	10.8	Int-Adv.	3	5.5	R	Suzuki
Q 615	M	15.9	Int-Adv.	8	10	L	RCM
R 616	F	12.1	Int-Adv.	6	6	L	Piano Adventures
S 617	F	13.1	Beg.	6	7	R	RCM
T 618	F	7.6	Beg.	3	4.5	L	Yamaha
U 619	F	5.8	Beg.	1	1	L	Yamaha
V 620	M	12.3	Beg.	4	4	R	RCM
W 621	M	10.1	Beg.	4	4	R	RCM
X 622	F	10.1	Beg.	4	4	R	RCM
	M: N = 11 F: N = 13	Range: 5.8 – 15.9 Mean: 11.46 Median: 12.2	Beg.: N = 13 Int-Adv. N = 11	Mean: 4.5 Median: 4	Mean: 5.45 Median: 5	Right hand: N = 19 Left hand: N = 5	

Appendix 8K: Population Pyramids Frequency Distributions for Gordon's Measures of Music Audiation Test Administered in Chapter 4, Article 3

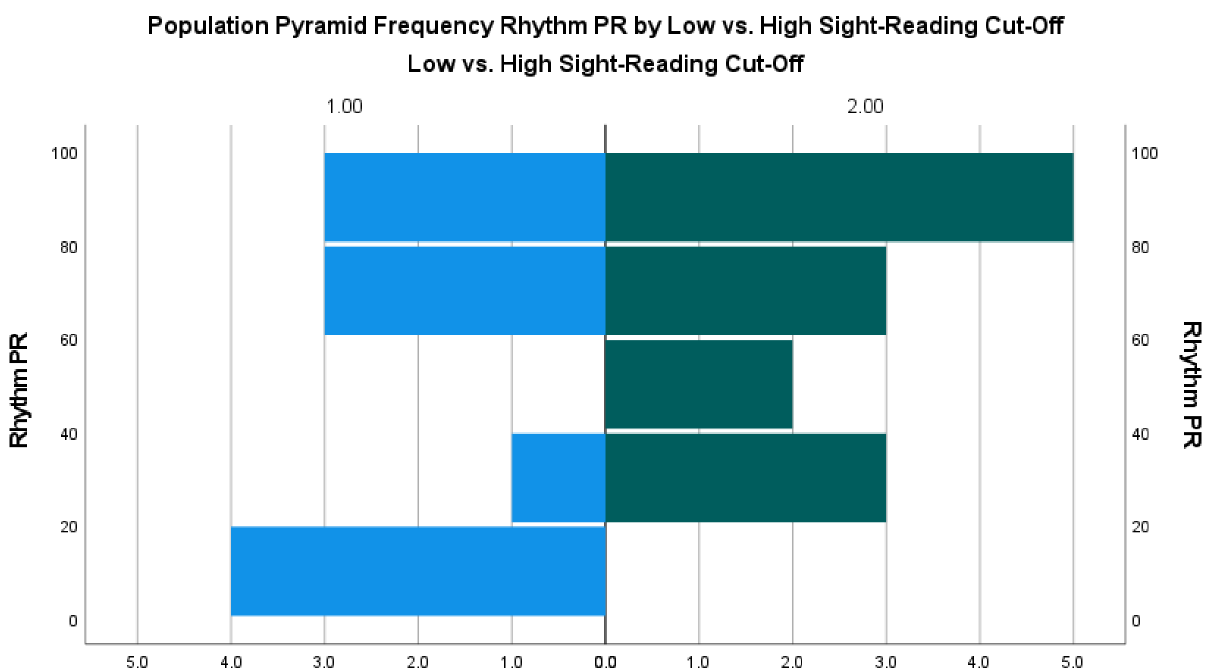
Composite Percentile Rank



Tonal Percentile Rank



Rhythm Percentile Rank



Appendix 8L. Interview Guides

For the parent

Required documents:

- Scan of recent report card
- Scan of recent piano exam (if applicable)

About the parent(s)

1. Could you speak to your own experience with music and music lessons?
2. Could you speak to your spouse's experience with music and music lessons?
3. What is your education level?
4. What is your occupation?
5. What is your spouse's education level?
6. What is your spouse's occupation?

Child's background information

7. What is your child's birthdate?
8. Where was your child born?
9. Where does your child live now?
10. Which languages does your child speak? If multiple, do they speak them all at home?
11. How was your child's development of language skills?
12. At what age was your child diagnosed with dyslexia?
13. Does your child like to read books at home?
14. How was your child's development of motor skills?
15. Which hand(s) does your child prefer for writing?
16. Did your child enjoy listening to music when they were young? Could you elaborate?
17. Did your child enjoy singing songs when they were young? Could you elaborate?
18. Does your child wear glasses during every day activities? (ex. at school, during piano lessons)
19. How would you describe your child's temperament?
20. Does your child have any siblings?
21. If yes, do the siblings also take piano lessons or other music lessons?
22. If yes, do they have the same teacher and use the same lesson books?
23. Do you notice any differences between how your children are learning music?
24. What grade is your child in at school?

The child's piano lessons and other activities

25. What inspired you to enroll your child in piano lessons?
26. At what age did your child begin piano lessons?
27. How many piano teachers has your child had? If multiple, elaborate.
28. Who is their current teacher?

29. How long have they been teaching piano to your child?
30. Please elaborate on the relationship your child has with the piano teacher.
31. Please elaborate on the relationship you have with the piano teacher.
32. Does your child enjoy their piano lessons?
33. Does your child enjoy practicing at home?
34. How many days per week does your child currently practice?
35. How long are the practice sessions, on average?
36. Does your child demonstrate and/or report to you any of the following vision problems when playing piano? (near-sighted, eye-strain, eye-fatigue, double-vision, blurry-vision, headaches, inattention, red eyes
37. How frequently does your child attend musical concerts? Please specify an answer prior to the COVID-19 pandemic and currently.
38. Does your child participate in any other musical extracurricular activities? Please elaborate.
39. Does your child participate in any non-musical extracurricular activities? Please elaborate.

For the child

Piano lessons:

1. How old are you now?
2. How old were you when you started piano lessons?
3. Who is your piano teacher?
4. Have they been your only piano teacher?
5. What books are you using in your piano lessons?
6. Do you enjoy your piano lessons?
7. What kinds of activities do you enjoy doing in your piano lessons? Why?
8. What kinds of activities do you not enjoy doing in your piano lessons? Why?
9. What kinds of activities do you think are easy in your piano lessons? Why?
10. What kinds of activities do you think are difficult in your piano lessons? Why?
11. Do you prefer playing from the sheet music or playing from memory?
12. Do your parents help your practice piano at home?
13. Do you enjoy practicing at home?
14. Have you completed a piano exam before?
15. If yes, did you like the experience?
16. Have you played piano in front of people before?
17. If yes, did you like the experience?

Music at home:

18. Do you listen to music on the radio? Who are your favourite singers? Who are your favourite musicians?

19. Do you listen to piano music?
20. Do you listen to music with your family?
21. Do you attend music concerts with your family?
22. Do you play any other instruments at home? Which?

School & music at school:

23. What grade are you in at school?
24. Which subjects do you like the most? Why?
25. Which subjects do you not like? Why?
26. Which subjects do you find easy? Why?
27. Which subjects do you find difficult? Why?
28. What are you learning about in music class right now?
29. Do you sing songs in music class?
30. Do you play instruments in music class? Which instruments?

Appendix 8M. Transcript coding

Life stage	Theme	Evidence
Early childhood	FI	Family tradition started when young • Like, um, I don’t know what it’s called, but on Sunday, ‘cause uh, ‘cause we usually put on some music in the morning. I don’t really know what music, though. • Yeah, my uncle picks the music. • Oh! [Laughs] Yeah, growing up as a kid, we always had, my dad always made pancakes for breakfast, so my older brother lives with us, so he carried on with the tradition. So, every Sunday morning, it’s a leisurely morning, we have pancakes for breakfast. So, my brother, ‘cause he’s got Spotify, so he just puts on music all the time. Ah, no kidding, so she notices that eh? [Laughs] Family concerts • But, other than that, probably a little bit of everything. I like, more the folk stuff. A little bit of classical. But Christopher had started giving us for Christmas presents, we’d go, he’d give us tickets to like, to the Symphony, so we’d taken them, a few of the kids, for Symphony Sunday afternoon, Early observations on language development and advocacy • I would say all of my kids, right from the get go, I… they were always very articulate, very clear, like I could always understand what they were saying. So yeah, that was never an issue. But it’s yes, yeah more when she started to read, and I started to do music with her and stuff I was like, okay, there’s something going on here. • Like, he caught on really quick. So, then I’m struggling, I’m like, okay, is he just really, really bright and Eloise is normal, or is Eloise actually struggling? I would actually get really frustrated, ‘cause like she just wouldn’t, she wouldn’t pick up on things. She just wouldn’t, couldn’t learn you know, the notes or whatever. You… I would sometimes it’s… the best way I can explain how it seems like, she has trouble processing and retaining information, I guess is the best way to put it. And so of course, because I started the music when they were so young, I noticed that before the school, with reading. But it would be like, it would be just… take her so long to catch onto anything. You have to go over it, over and over and over so many times. And then, you know, one day, it seemed like she knew it, and then you’re like [sigh] okay, and then you’d go back the next day, and she doesn’t remember it anymore. And I’m like… I would go through these stages I’m like, ‘Do you really not know it, or are you pretending you don’t know it?’ Like, it was just, like she couldn’t retain it. Like, you’d think she finally gets it, and it wasn’t there again. okay that’s what that is, I got, I’m good, I know it.’ • And so, you know, I would talk to her teachers at every parent-teacher interview, and it was like ‘How is she doing at school? Because to me, there’s something going on.’ It wasn’t until she was in grade two at Christmas time that her teacher finally approached me and says, ‘You know she’s behind a grade level in reading’ and I’m like ‘I could have told you that; I know there’s been something going on here.’ And then that’s what kind of started the whole process. We had her… did a bit of speech pathology assessments, and then um, a psych-ed assessments and stuff
	PATL	

<table>
<tr><td rowspan="2">Early music lessons</td><td>FI</td><td>Relating experiences to sister:
I think I was about six years old. I think, because my sister started it when she was six, so I think I was six years old
Yeah [goes to piano]. I was using… these are my sister's [shows books to camera], but I was using the [Piano] Safari one.
Reason for taking piano lessons:
Uh, well, my mom wanted me to see if I liked it, so.
Reason for enrolling Eloise in piano:
[Laughs] So it was a desire, then, to share your musical experiences with them, by having them take lessons, too. Yeah, it's just a good thing to have. I mean, what adult do you talk to who ever regrets having to take lessons? It's either… [looks at spouse, off camera, says, 'you regretted taking lessons'?]</td></tr>
<tr><td>PATL</td><td></td></tr>
<tr><td rowspan="2">Present day</td><td>FI</td><td>Family involvement in music and practice
Uh, sometimes my sister listens. Because my brother has to go to school early because… yeah.
Uh, I played a duet with my grandma but not my siblings.
Well, we learnt it together. It was a Christmas piece, but I can't really remember it anymore.
She likes music, that's the other thing about her, like, we got her a little karaoke machine for Christmas, 'cause like, she loves to sing along to music and stuff like that. So, like, she enjoys music
She's usually sings to Nicole, her younger sister. But sometimes I'll walk in there. Me, too. And then she doesn't like it because I join her. [laughs]
So, then, you've been a bit more familiar then, with the piano teacher? How is your communication, through email or in person? Whenever they have a lesson…
I hope so. I mean, she seems to enjoy it. You know, it's always one of those things as a parent, like you don't want to force your kid into doing something they don't want to do, but then it also comes down to that whole thing about, you're a kid, and you don't want to do it, and then your parents let you quit, and then, as an adult, you're like, why did you let me quit? And I don't know. To me, music is so important, and it gives you so much. So, I don't want them to quit
Family music making
But yeah, well sometimes. It's more when my mom's out. My mom will tend to play more with the kids and practice more directly with the kids than I will, and I know she'll get them playing duets and stuff. But I have played with Tyler [oldest son] before. Tyler also does the violin. So, I'll kind of play the piano part when he does his violin and stuff. I would like to do more, but it's [sigh] sometimes time, right? Three kids, you're working, and it's just so hard to fit it all in. But, yeah.</td></tr>
<tr><td>PATL</td><td>Attitudes toward piano
[Shrugs] Um, playing the piano? [Laughs]
Well… I like learning new songs.
I like playing songs.
Uh, I like playing songs.
I kept going.</td></tr>
</table>

		• Um, I'm looking forward to more recitals. • Most of the times, I just play it from heart, 'cause I know the song really well. • Great. I'm just looking at my questions here. Do you enjoy practicing at home? Yeah. • Well, I played piano in… at school in like, kind of like a handbell recital. For like, um, a piece in between the handbells, so yeah. • she forgot and stumbled, and I looked over at Nancy, and then she looked back, and she started again and fuddled her way through it, and yeah. So, good for her. Attitudes towards learning generally • I just like learning about the human body, and like, how it works. And then in science I like learning about, like all… I don't really know how to explain it… • Yeah, I also like um [long pause], last week, we made, um, we made an electric car. So, it had a solar panel, connect to a little… connect to a motor. And then, we went outside. It didn't run because there wasn't enough sun. But um, you could hear the motor, like, running. • Well, what I like learning about in social studies is like, about the wars. Attitudes about tutoring • She has a really amazing attitude about things. Like, I mean she's in math tutoring and stuff, and even the math tutors have said, she's got an amazing attitude, like she tries, right. Like, you get most kids who go to a tutoring place or whatever, and they're like 'I don't 'wanna be here, I don't need to be here,' but like, she tries. She hates missing school, she's scared she's 'gonna get behind, so she struggles. But it's not through lack… yeah she tries. Like, she's always willing to do something. Like, she'll do what you ask. She's always willing, um, yeah. Attitude generally • Yeah, in general, like with school and everything, like if you ask her to do something, she's a pretty willing kid. Unless, you know, she's with her siblings, then they fight and stuff, but she's uh, and even like the teachers at school say she's like, a nice kid, she'd always try to help, always willing to do stuff, yeah, that's kind of her general attitude, for everything, really.

Notes: FI refers to 'family involvement' and PATL refers to 'positive attitude towards learning'