Examining the relationship

between music training and early reading skills in children

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Abstract

Past research has found evidence of a link between musical perception and performance on literacy related tests, such a reading tests and phonological awareness measures. Particular focus has been on the correlation between musical skills and phonemic understanding, with few studies examining reading specifically. Thus far in the literature, it is unclear if the relationship between perception and reading is dependent on specific perceptual abilities or is more domain general. Past investigation is also limited in the musical tasks that are available for children, and this had led to very mixed results as to why the relationship between music and reading might exist. The present study tested 120 6- to 10- year olds on a variety of musical perception measures and word reading tests to examine the association when controlling for general cognition and length of music training. Our results revealed that speed and tuning perceptual abilities were the only significant predictor of word reading scores, and that music training was uncorrelated with reading ability.

Learning to read is a complex process that has been the subject of intense scientific study. Early reading skills are significant predictors of later academic success and important elements for school readiness in young children (Duncan et al., 2007). Therefore, it is very important that strategies aimed to improve early reading skills are based on empirically supported relationships. Past research has suggested a connection between music perceptual ability and the ability to read (Flaugnacco et al., 2015; Huss, Verney, Fosker, Mead, & Goswami, 2011; Tierney & Kraus, 2013). Why might this connection exist? When considering what processes are involved in reading, it is most popularly understood as a visual process of reading letters and decoding meaning using high level cognitive ability. Often overlooked is the fact that reading is largely a sound-based skill. To read words on a page involves several discrete skills: first, the reader must have an understanding of the language being read; second, he must know how to sound out the words, and third, he must understand how the letters correspond to sounds to form words (Bolduc & Lefebvre, 2012). This basic understanding of word formation is first heard in spoken language; therefore, reading is heavily associated with auditory based skills. The present study examined the specificity of the link between music perception and reading.

Music perception and reading likely rely on similar aspects of processing. Broadly, both require high level cognitive processes such as use of working memory, efficient and fast neural processing, and focussed attention (Cain, Oakhill, & Bryant, 2004). Reading and music perception also require the learner to decode and organize information and connect it to abstract meaning. The individual processes that contribute to reading itself should also be considered because reading is not one isolated skill. A reader must first decode or identify the word in front of him, and then interpret the meaning of the words around it to comprehend the meaning of the sentence as a whole. These represent two different processes, known as decoding and comprehension (Snowling & Hulme, 2011.) Decoding at a basic level depends on the reader connecting what they are reading in print to verbal language they have heard. Processes that contribute to strong reading skills are a combination of both high level cognitive abilities and lower level perceptual skills. An inability to process sound efficiently has been hypothesized to lead to reading deficits (Hornicke & Kraus 2013). More specifically, sound processing in reading relies on semantic and phonetic awareness, which enables the reader to translate auditory information into reading ability. Phonetic awareness itself relies upon the ability to detect subtle changes in timing and frequency in different sounds that convey substantial differences in meaning in language (Tierney, & Kraus, 2013). These high level cognitive processes of decoding and comprehension may build on perceptual processing in language.

An awareness of phonemes has been found to be of utmost importance for reading skills (Lundberg, Olofsson, & Wall, 1980; Nation & Hulme, 1997). Phonemic awareness is knowledge about sounds in language, and how to decompose words into their component phonemes. It is also the understanding and ability to manipulate words by adding, deleting, segmenting and combining different sounds . A longitudinal study conducted by Byrne, Freebody and Gates (1992) found that children who scored low on decoding and phonemic awareness tests in grade 1 also scored very low on comprehension in grade 3. This study demonstrates the multifaceted nature of reading in which deficits in one area can lead to serious consequences in others. Many researchers argue that the ability to perceive and manipulate phonemes is critical for the development of later reading skills (Gromko, 2005; Lundberg, Olofsson, & Wall, 1980; Nation & Hulme, 1997). Snowling and Hulme (2011) conducted research on readers with dyslexia and found that inability to decode words and low reading comprehension were two independent impairments. However, decoding difficulties were related to phonological awareness. This can be especially difficult in languages such as English, in which many letters have multiple pronunciations when combined with different letters. It is critical for children to begin reading with refined processing of verbal sounds in speech (Snowling & Hulme, 2011). Problems with word decoding did not necessarily reflect higher order cognitive delays, whereas problems with reading comprehension did. Reading comprehension impairments were predictive of poor performance on word meaning tasks and understanding of grammar. Evidence such as this could provide a basis for the relationship between reading and musical perception. Because phonemic awareness requires fine tuned auditory perception, it could be that readers who have better musical perception skills may also have greater phonemic awareness.

Evidence from music training studies supports the link between music perception and phonological awareness. Standley (1996) found that overall, music training leads to gains in phonological awareness, and in children with reading difficulties such as dyslexia, music intervention actually improved their reading levels. It should be noted that Standley defined “music training” very broadly and included many studies that simply used music to reinforce behaviour changes. Further research by Degé and Schwarzer (2011) compared preschoolers matched for age, intelligence and socioeconomic status across three different training conditions: music, sports, and phoneme training. The children were trained for 10 minutes a day over 20 weeks and those in the phoneme and music groups showed significant gains in phonological awareness. The sports group showed no significant improvements. Degé and Schwarzer argue these results are evidence of a shared learning mechanism between music and reading. In another longitudinal study on the links between music and reading followed kindergarten students for two years and tracked the extent of their music training (Moritz, Yampolsky, Papadelis, Thomson, & Wolf, 2012). Children with more music training, particularly those with strong rhythm skills, demonstrated better phoneme segmentation abilities at the end of kindergarten. Rhythm ability in kindergarten was also strongly related to the child's phonological awareness and word identification ability in grade two. A meta-analysis by Gordon, Fhed and McCandliss (2015), also reported a modest effect of music training on phonological awareness. In sum, many quasi-experimental studies have shown a strong association between music and phonological knowledge, even over many different types of tasks and environments.

The link between music training and reading specifically is not as apparent as the link between phonological awareness and music training however. Many studies have analyzed music training groups compared to control groups, also accounting for other extracurricular activities not involved in music. A correlational study conducted by Banai and Ahissar (2013) examined the relationship between music training and performance on reading and auditory perceptual tasks. Their study found that children with previous music training were highly unlikely to have memory or auditory perception problems, even if their training period was very short. However, their results showed that music training did not predict reading ability when controlling for overall cognitive ability as measured by the Ravens Matrix (Raven, 1938). A correlational analysis by Tsang and Conrad (2011) also found that children with music training performed better on phonological awareness tests, however they did not show a significant advantage in word reading tasks. Therefore, perception only predicted reading scores if the child had not been exposed to music lessons. Further, the meta analysis conducted by Gordon et al., (2015) found the impact of music training on reading ability was weak. The authors suggest that there is likely not a direct link between music training and reading ability, but it is more likely a gradual bootstrapping process. The process begins with children learning to attend to auditory information and then build stronger phonological skills based on those first steps. Overall there is a lack of concrete evidence of a direct link between music training and reading skills. It is possible that the researchers found these results because the sample they studied was children who had selected certain extracurriculars and therefore there might be something systematically different between the two groups that is uncontrollable in a correlational study. The important point in Tsang and Conrad's (2011) study is that research examining the relationship between music training and reading should carefully control for the factor music training. Gordon et al., (2015) also highlight the importance of controlling for factors such as IQ and SES to rule out the effect of cognition as a third variable.

Often studies that met the inclusion criteria for the meta analyses were limited in the populations they studied, and many did not use true random assignment. Frequently children being studied are those who are already in music training programs, which is then a self selected group, so results should be interpreted with caution. However in studies on special populations, results show that children with dyslexia perform worse than control groups on melodic discrimination tasks, and that children with music training outperform both impaired and control groups (Foregeard et al., 2008). It was argued these results are evidence that music training improves auditory discrimination and overall vocabulary. Studies have also suggested that music intervention may lead to improved outcomes for children with reading impairments such as dyslexia (Overy, 2003). The research on music training and reading reveals unique positive correlations and improvement in specific capacities with specific populations. Largely though, the results on the impact of musical training on reading are highly inconclusive. Some studies find improved performance on reading tasks and others cannot replicate those findings.

Overall, the literature on this topic is mixed. Some studies have found both correlational and causal evidence that musical training improves many skills such as phonological awareness and improved reading levels (Standley, 1996). However other studies do not support these findings, or find a smaller effect of reading compared to phonological awareness (Gordon, Fehd, McCandliss, 2015). Theoretically, it is logical that music training would increase reading ability. The two rely on very similar neural processes, such as long term memory that is needed to both remember musical notation and letter recognition. Both also rely on working memory that is needed to decode and fluently read music notes and letters. More obviously, reading relies on decoding auditory information, as does music training. Efficient and dedicated attention capacity is also required by both the early reader and early musician, as they learn the basics of their task.

If reading depends on auditory skills, this raises the question of what aspects of auditory processing it would rely on most. Is pitch perception more integral to early reading skills than awareness of rhythm? Or is it possible that reading relies more on general auditory perceptual abilities and is not specific to certain perceptual processes? Different theories exist to explain how reading is linked to auditory processes. Some of these theories are timing specific; that is, they suggest that reading relies on auditory temporal information that helps the listener hear phonemes and develop sound and syllable recognition (Goswami et al., 2013; Leong, & Goswami, 2014). Other theories take a more general approach, suggesting that a specific relationship between auditory processing and reading is unlikely (Schellenberg, 2015).

Past research on timing-specific theories has produced mixed results. Rapid auditory processing theory was one of the first proposals to explain why children with specific language impairments and dyslexia may be impaired, proposed by Tallal (1976). Tallal argued that impairments in reading were the result of delays in auditory processing that cause the listener to miss valuable auditory cues. She hypothesized that a listener is bombarded with auditory stimuli extremely rapidly and that the auditory system must be highly efficient to encode the sequence of information it is receiving. Her research indicated that children with dysphasia were unable to discriminate speech sounds that are composed of rapidly changing acoustic spectra; however when that stimuli was slowed down for them, they were able to discriminate those same sounds (Tallal & Piercy, 1973). Nittrouer (1999) conducted subsequent research on Tallal's (1976) hypothesis, also using a sample of children with severe reading impairments. This study compared a group of children with normal reading skills to a group of same aged children with poor reading scores. Results found that children performed the same on tasks requiring them to recall sequences of nonspeech tones presented at varying rates, which is not supportive of Talall's findings. Overall, further study of the rapid auditory processing theory did not yield successful support for these claims (France et al., 2002; Habib, 2002, Ramus, 2003;). However, this theory initiated substantial research on temporal deficits in people with reading impairments.

Although early studies failed to find evidence that reading relies critically on rapid auditory processing, much research suggests that reading abilities are associated with temporal processing. For example, it has been suggested that rhythmic processing delays lead to reading impairments (Flaugnacco, et al., 2014). Rhythmic awareness can be assessed by the ability to reproduce certain patterns of rhythm. Studies on adults with dyslexia have found that an inability to tap along to a rhythm is correlated with problems reproducing language (Thomson et al., 2006; Wolff, 2002). One way that rhythm is conceptualized is the pattern of short and long note durations in music. Participants may listen to a certain song and then be asked to replicate the rhythm by tapping it out with their fingers. Rhythm plays an important role in speech because awareness of timing conveys a lot of information. Research shows that individuals with dyslexia have worse temporal processing than typically-developing controls (Flaugnacco et al., 2008; Meyler, & Breznitz, 2005). This may lead to decreased ability to detect important auditory information that is present in both music and language, such as an inability to recognize patterns in auditory information. Further, Overy (2003) found that dyslexic children showed impaired performance on various temporal tasks such as rhythmic motor skills and rapid auditory processing skills. However, the results of her study did not find evidence of pitch impairments so she argues instead for timing related deficits. Temporal processing involves many elements of perception including rhythm awareness, beat perception, and also the neural processing involved in auditory perception. These processes have been the focus of study for many researchers examining the relationship between musical perception and reading.

Due to evidence of a link between temporal processing and reading, one newer theory proposes that the core deficit of dyslexia is impaired low frequency phase locking. Usha Goswami (2011) argues that individuals with dyslexia are unable to properly phase-lock neural oscillations to periodic changes in auditory input, in a theory called the Temporal Sampling Framework. In a typically developing individual, neurons fire in sync with a regularly occurring auditory pattern (such as a pattern of stressed syllables in speech) that enter the ear, and this assists the listener to attend to the most important information conveyed in those sounds. This process is called phase locking. Phase locking influences the listener’s ability to detect what is called rise time, which is a measurement of how the sound wave is received by the auditory system. Rise time is the amount of time it takes to notice a change in the amplitude of the sound wave. It is a critical factor in detecting syllable stress, which conveys considerable emotional meaning in spoken language. Research has shown that individuals with dyslexia have difficulty completing rise time tasks, which supports the temporal sampling theory (Goswami, 2011). According to this framework, individuals with dyslexia should also be impaired on tasks that assess beat processing, and research finds this is in fact the case (Huss et al., 2011) . This has significant implications for dyslexia because Goswami argues that an inability to attend to the appropriate acoustic cues in spoken language would then impact the ability to read and make proper letter sound associations. She further argues that phase locking delays would also contribute to impaired rhythmic entrainment, or an inability to detect beat. This framework is based on results that children and adults with dyslexia perform worse on rise time perception tasks and tasks requiring them to tap out a beat (Wolff, 2002; Goswami 2011; Goswami et al., 2013). However, these findings are controversial.

Other research has failed to find evidence consistent with Goswami's (2011) Temporal Sampling Framework. Papadopoulos, Georgiou, & Parrila (2012) found contradictory evidence in a large sample of Greek children. Specifically, performance on beat perception tasks was unrelated to the children's performance on phonological and reading tasks. Further, the results of this study showed that beat perception deficits are also found in developmentally typical children who scored well on reading measures. These results are likely due to the irregular orthography of the English language, which is quite complex compared to Greek. Studies supporting the Temporal Sampling Framework failed to control for cross language comparisons, so the data is not reflective of a diverse sample. However, Goswami et al., (2017) did find evidence of rise time sensitivity predicting phonological awareness in English, Spanish and Chinese. These findings did provide evidence of a common neural basis for dyslexia. A study of Greek children found that beat perception had no significant impact on reading and phonetic awareness (Georgiou et al., 2010). This is likely because Greek is a more straightforward language in terms of spelling rules and phonetic representation of letters. A study by Hansen and Corrigall (2016) also failed to find evidence that beat processing was correlated with reading, although rhythm processing played a more key role; however, these results were found in a typically-developing adult population rather than a group of children with dyslexia. Therefore, rise time and beat perception impairments on their own are incomplete explanations for reading delays.

Associations between pitch processing and reading-related skills provide further evidence against timing-specific hypotheses. Some studies have found that at least at certain ages, pitch processing is correlated with phonemic awareness (Anvari et al., 2002; Loui et al., 2011). For example, Anvari et al., (2002) found that music perception skills were predictive of reading ability even when controlling for other cognitive abilities. Their results demonstrated that for children 5 years of age, pitch perception accounted for a significant amount of the variance in reading scores, even after controlling for other cognitive abilities. Similarly, Loui et al. (2011) examined how phonemic awareness relates to pitch perception. This study found a significant positive correlation between pitch perception and phonemic awareness in 4- and 5-year-olds with a correlational coefficient of .59 (5-year-olds) and .47 (4-year -olds). These findings are significant because they show an association between the inability to discriminate pitch, or tone deafness, and dyslexia, which may imply shared impairments between the two disorders. This high correlation has never been found in other studies, with some studies failing to establish any significant relationship between pitch perception and phoneme awareness (Papadopoulus et al., 2012; Georgio et al., 2010).

Exaggerated effects are problematic in research on music and reading, and they happen based on a number of methodological factors. Small sample sizes can contribute to exaggerated effect sizes, which leads to misconceptions in the literature. Loui et al. (2012) was limited by an extremely small sample size (N=16) which may have led to their unprecedented results. An additional problem in much of the past research involves task demands. It is common practice to assess rhythm and beat perception by asking participants to reproduce a rhythm or a beat by telling them to “tap it out” after a segment has been played to them (Overy, 2003; Wolff, 2002). For adults, tapping tasks may be an acceptable assessment of their auditory perception abilities; however, for children that may not be the case. By adding motor demands to the perceptual test, this complicates the expectation and may not accurately reflect the child’s beat or rhythm awareness.

There are a number of common limitations in many of these studies examining the association between musical perception and reading. For example, many researchers use narrow musical test batteries, including musical measures that only examine one or two musical processing abilities, such as pitch and rhythm tasks (Loui et al., 2011; Thomson et al., 2006; Wolff 2002) . The use of poor musical stimuli is another common problem, where researchers use sine tones and sequences of tones that are not musical in perceptual properties (Leong, Goswami 2014; Goswami et al., 2013). These tones can however be easily created and manipulated in laboratories, which makes them popular to use. This does call into question the ecological validity of the measures because they do not reflect music children encounter in the real world. In addition to these limitations, many tasks in these studies use tasks that have high working memory demands. That is, the participant is required to listen to a single auditory excerpt, and then is asked if a second excerpt is the same or different from the first. This task can be criticized as relying too heavily on memory and then complicates the task from being strictly a measurement of auditory perceptual ability. To control for this problem, the music discrimination tasks in the current study played the initial excerpt twice, to try to reduce memory demands. Lastly, task procedures are often poorly designed to meet the needs of children; for example, the trials can be very long and numerous (Huss et al.,2011; Forgeard et al., 2008) leading to participant fatigue, which is quite problematic in children. The present study was designed to maintain children's attention and avoid fatigue-related problems by alternating between cognitive and musical tasks to vary the test stimuli. We also used visuals and puppet characters in the tasks to help with child engagement in the procedure. By using more appropriate and engaging methods, the results of the study should offer more clear cut evidence about the relationship between music perception and reading.

In the current study, we examined the specificity of associations between music perception skills and word decoding abilities in 6- to 10-year-old children. Specifically, we examined the relationship between word decoding skills and melody, accent, tuning, and speed discrimination, as well as the ability to perceive the beat. The current hypothesis builds upon a review article published by Tierney and Kraus (2013) who argued for a more domain general approach to music and reading ability. We hypothesized that if tasks are more carefully designed, then a more general relationship will be found empirically between reading ability and musical perception. That is, children who are better readers will be better at detecting various perceptual elements in music, because the neural networks responsible for processing auditory information will be stronger. Further, it is critical to control for other variables such as extracurricular activities, family income and IQ, which many studies fail to do. This is important to do because past research has found that when controlling for IQ, sometimes the relationship to reading scores disappears (Swaminathan, Schellenberg., & Venkatesan, 2018). Swaminathan et al., also argue the importance of controlling for pre-existing individual differences such as personality and musical aptitude. Past research has shown there is a direct association between different facets of the Big Five, specifically openness and conscientiousness, that relate to music training (Corrigall, Schellenberg, & Misura, 2013). By controlling for these factors, a regression analysis will explain many relationships that may exist among these variables.

Our sample for the present study was 121 6- to 10-year-old children. We expected that children with high scores on musical perception tasks (Mini-Proms, Beat Alignment Task) would also have high word reading scores (Wide Range Achievement Test), as well as strong vocabularies (Peabody Picture Vocabulary Test). We controlled for cognitive abilities as well as socioeconomic factors such as income and parental education level.

Methods

Children between the ages of 6 to 10 years participated in the study (N = 120, 57 girls and 63 boys, mean age = 7.71 years, SD = 1.32). The children were either tested in their school, home, or in the MacEwan Child Lab. Background demographic information and history of music training for each child was provided by the parents in the form of a questionnaire.

Demographics

1. Parent questionnaires.

Parents were instructed to fill out a brief survey either online or on paper to provide basic demographic information about their child. These questions included information about what languages the child spoke, and what language was primarily spoken in the home. Socioeconomic status was assessed through parents checking off a bracket of their yearly income and indicating both mother's and father's highest level of education obtained. Income brackets were broken down into the following categories: 1= < $25 000, 2= 25 000-49 999, 3=50 000-74 999, 4- 75 000- 99 999, 5= 100 000-124 999, 6= 125 000- 149 999, 7= 150 000- 174 999, 8=175 000- 199 999, 9= > 200000. Educational brackets were broken down into the following categories: high school or less =1, some college= 2, university degree= 3, masters or professional degree = 4, Ph.D = 5. The brackets for income and education were averaged between the mother and father to give an estimate of socioeconomic status. The average annual income for the families in this sample was 125 000 – 150 000. The average education level of the parents was "some college education". Parents indicated their child's exposure to music training and other music-related and non-musical extra-curricular activities. Music training was assessed as duration (in months) of music training, number of instruments, and age of onset of music training. The total months of each instrument were added together to give a total amount of exposure. Twenty four of the eighty one children had received some form of music training. Mean length of training in the present study was 4.5 months with a standard deviation of 13.45. Mean length of non-musical extracurricular activities was 8.02 months, with a standard deviation of 16.78. Parents were also asked how many hours per week their child spent reading; the average was 4.78 hours per week with a standard deviation of 3.41.

Personality

2. The big five inventory (John & Kentle, 1991).

The Big 5 was also completed by parents to assess children's personality factors. Using a five-point Likert scale from strongly disagree to strongly agree, parents responded to 44 questions based on how open to experience, agreeable, conscientious, neurotic and extroverted their children were.

Music Perception Tasks

3, Mini-profile of music perception skills (Law, & Zetner, 2012; Zentner & Strauss, 2017).

The children completed a standardized musical perception task and an abridged version of the Mini Profile of Music Perception Skills (Mini-PROMS) (Law, & Zetner, 2012; Zentner & Strauss, 2017). It was composed of four subtests assessing melody, tuning, accent and speed perception. This test has satisfactory internal consistency and test retest reliability > .85 in adults

(Law & Zetner, 2012), . The coefficients for the subtests themselves are acceptable at .56 to .85. The convergent validity with Gordon's Advanced Measures of Music Audiation and Musical Aptitude Profile and the Musical Ear Test (Law, & Zetner, 2012). However this test is relatively new, and in terms of reliability for use on child populations, the evidence has not yet been established. The test was administered on a MacBook laptop to participants using Psychopy (Python) software (Peirce, 2007). Children were given headphones to ensure uninterrupted listening. Researchers also kept a pen and paper record of the participant's responses in case of computer problems.

In all four subtests, the participant was played three samples of music stimuli: the same stimuli were played twice, and the third stimulus was either the same or different than the first two. This sound presentation was aided with a visual indicating to the child when it was time to listen to the two samples and when to compare the test excerpt. In the melody subtest, the third excerpt was either the same or a different melody played. In the accent subtest, the third excerpt was either the same or different stress patterns of sound. In the tuning subtest, the third excerpt was either the same or differently-tuned chord. In the speed subtest, the third excerpt was either the same or different tempo as the first two excerpts. In total, the mini-PROMS was composed of 36 trials, ten trials for each of the melody and accent subtests, and eight trials each for the tuning and speed subtests. Children were asked to respond to the third stimulus as "same" as the first two, "different" than the first two, or "don't know". One practice trial was played at the beginning of each subtest, and the child was given feedback about their answer.

4. Beat alignment test (BAT) (Einarson & Trainor, 2016; Iverson & Patel, 2008).

This task had participants watch two consecutive videos of puppets drumming along to the same song. One puppet drummed synchronously with the beat and the other drummed out of sync with the beat, and the child was asked to select the puppet that "wins the prize for the best drumming". The puppets in this task were matched to look similar to each other to avoid children selecting based on aesthetics. In total, there were 12 dyad trials presented in this task, for a total of 24 puppet videos. One practice trial started the test, in which the child received feedback on whether or not their answer was correct. The trials in this task were separated into two parts. One half of the test assessed phase perception and the other half assessed tempo perception. The two parts were separated by an attention trial in which one animal was obviously out of sync with the beat to assess that the child was still attending to the stimuli. This test was counterbalanced between subjects and presented in one of four orders to each participant, so that the order of videos in the task were semi-randomized. Specifically, the correct puppet was presented first on half the trials and second on the other half of trials. The side the correct puppet was presented on when asking the participant to choose which puppet drummed best was also counterbalanced from left to right. The order of the test was also switched each time to control for a practice effect, meaning that tempo was presented first to half the participants, and phase was presented first to the other half of the participants. In phase trials, the out-of-sync puppet was drumming too early or too late, and in the tempo trials the out-of-sync puppet drummed either too fast or too slow. Children were asked to indicate which puppet they thought was the better drummer, and then indicate how sure they were on a confidence interval ranging from "I'm guessing" (coded as a score of 1) to "I think so" (coded as a score of 2) and finally, "I'm totally sure" (coded as a score of 3). Scores were calculated ranging from -3 to +3. The child received positive points for identifying the correct puppet and then scored from 1-3 on their confidence interval. The child received negative points for identifying the wrong puppet and then scored based on their confidence level. To receive a full +3 point response the child had to get the correct puppet and be “totally sure”. If they selected the wrong puppet and they were totally sure, the score was -3. This task measured the child’s ability to perceive the beat in music.

Cognitive and Literacy Measures

5. Wide range achievement test version 4 (Wilkinson & Robertson, 2006).

Children completed the word reading and spelling subtests of the WRAT Version 4 (Wilkinson & Robertson, 2006). In the word reading test, children read individual words aloud to the researcher and answers were scored based on correct pronunciation. Children under 8 were required to pass an individual letter reading test before beginning the task. The spelling subtest required children to write out words read aloud by the experimenter. For children under 8, an individual letter writing portion was included as a precursor to the spelling test. The words were stated once, then read aloud in the context of a sentence, and then stated again. These subtests provided a benchmark of early reading and spelling ability. These scores were standardized based on American norms.

6. Peabody picture vocabulary test 4th Edition (PPVT-IV) (Dunn & Dunn, 2017).

The PPVT-IV (Dunn & Dunn, 2017) was administered to all participants. Children were asked to point to or say the number of the picture (out of four possibilities) that illustrated the word that was read aloud to them. The raw score of this test was then standardized based on American norms. The PPVT-IV measures receptive vocabulary and gives a strong indication of the participants’ intelligence because it is highly correlated with IQ scores (Hodapp, & Gerken, 1999).

Procedure

The test as a whole took approximately one hour per participant. Subtests were ordered in an attempt to keep the children engaged in the tasks by alternating music tests with cognitive tasks. Children began the study with the melody subtest of the Mini-PROMS, followed by word reading (WRAT-IV), tuning (Mini-PROMS), spelling (WRAT-IV), accent (Mini-PROMS), PPVT, speed (Mini-PROMS), and finally the BAT. This order had the children switch between computerized listening tasks and writing and reading tasks to prevent fatigue. The children received a ten-dollar gift card for Chapters (a bookstore) for their participation.

Results

Due to incomplete data sets returned by the parents only data from 70 children could be used in the final analyses. Table 1 displays the descriptive statistics for the cognitive measures (word reading, spelling, vocabulary) as well as the performance on the musical perception measures. The table also includes the hours the children spent reading a week, and the months of music training as reported by their parents. First, we examined whether means for the cognitive measures were significantly different from published norms (Wilkinson,& Robertson, 2006), and we found they were not: word reading *($t= 3.671$, d (119)*) $p < 0.001$) spelling (*$t=2.965$, df(119), $p<0.01$)),* and PPVT (*$t=11.386$, df(119), $p<0.001$)).* None of the means or standard deviations on this task were significantly different from published norms.

Table 2 represents the simple correlations among predictor variables. The Mini-Proms measures showed some satisfactory inter-reliability between the subtasks and with the BAT. Melody was significantly correlated with the speed subtask and the BAT task. However, it was not correlated with tuning and accent. The tuning subtask showed significant correlation with the accent scores, however it was not significantly correlated with the BAT. Phase and tempo subtasks on the BAT showed a strong intercorrelation (*$r= .393$ at the 0.01 significance level, $n= 119$*). The speed subtask and BAT were both significantly correlated with age, and age had a positive relationship with months of music training. A significant relationship was also found between hours spent reading per week and age (*r*=.249 at the 0.05 signficance level, *p*=.025, *n*=119). Months of music training was found to be positively associated with openness, but no other personality facets were correlated with music training. Between the personality measures a positive relationship was found between agreeableness, openness and conscientiousness. A significant negative relationship was found between agreeableness and neuroticism. Reading scores were associated with both tuning perception and speed perception. Tuning scores showed a significant correlation with the word reading subtask (*r*=.316 at the 0.01 significance level, $p < 0.01$ *n*=120). Speed task scores were also significantly correlated with word reading (*r*=.232 at the 0.05 significance level, *p*=.011, *n*= 120). Tuning perception was significantly correlated with the PPVT score (*r*=.248 at the 0.01 significance level, *p*= .006, *n*=120). The PPVT score was also found to be correlated with reading scores (*r*=.424 at the 0.01 significance level, $p < 0.01$, *n*=120).

Further analyses of significant predictor variables and reading score was done using a hierarchal regression. This calculation determines what amount of variance is contributed by significant variables. When examining only general cognitive ability as measured by the PPVT, it contributed 18% (r^2= .180, *f*= 25.819, *df*(1,118)) to the overall variance in word reading scores. When accounting for performance on musical perceptual measures and cognitive ability, these variables explained 8.4% (r^2 = .840, *f*=6.651, *df*(2,116)) of the variance in reading scores. Step one of this regression controlled for cognitive ability using the PPVT score. Partial correlations for the effect of general cognitive ability (as measured by PPVT score) on word reading score was *pr*= .424. Step 2 of the regression calculated variance with the first factor and also accounted for the scores on tuning and speed perception measures. Tuning contributed a partial correlation of *pr*=.204 to the overall variance and speed contributed *pr*= 219. Performance on the speed and tuning subtasks, as well as scores on the PPVT, continued to predict reading with the other variables held constant.

Discussion

In the current study, we hypothesized that performance on tasks assessing music perception would be correlated with scores on the standardized word reading subtest of the WRAT in children ages 6 to 10. We found that tuning perception and speed perception were significantly correlated with word reading scores. Even after controlling for general cognitive skills as measured by the PPVT, music perception still predicted reading scores with those variables held constant. However, our other measures of music perception--melody, accent, tempo and phase- were not significantly correlated with word reading. These results indicate that in terms of the association between reading and music, both pitch and temporal processing seem to play a key role.

Our results provide further evidence for two different theories proposed in past research. The correlation between reading score and performance on the speed subtask could be explained by temporal theories that suggest timing is very important for learning to read. These findings are consistent with the findings of Flaugnacco et al., (2008) and Meyler, & Breznitz, (2005) who found that individuals with reading impairments have worse temporal processing than those without impairments. The present study's correlation between word reading and tuning may provide further evidence of the role of pitch in reading, as reported by Loui et al., (2011). Their study found that children who struggled to identify changes in pitch in pure tones also struggled with phonemic awareness tests (r= .800). The present study did not find a correlation that strong, but the relationship found here (r=.248) is consistent with those findings.

The results of this study indicate that certain perceptual skills are more associated with reading than others. No significant effects of melody or accent were found to have an influence on word reading scores. In addition, the BAT also showed no significant relationship with reading. This is an especially surprising finding because the BAT is specifically designed for use with child populations. The stimuli is also high in external validity because it is genuine music, and yet no association was found between beat perception and reading ability. The BAT was not shown to be a predictor of word reading in our study, which could mean that knowledge of beat and accent is not as crucial to the development of literacy as has been argued in previous research (Goswami, 2011). The strongest correlations were found between speed and tuning subtasks and word reading. This could be evidence that the association between music and reading depends more upon temporal processing than complicated perceptual processing such as beat and rise time awareness.

The results of this study show no impact of music training on word reading or on other cognitive measures. These results differ from those of Anvari et al., (2002), who found that musical perceptual abilities contributed unique variance to reading scores. The present results are consistent with those of Gordon, Fehd and McCandliss' (2015) meta-analysis which found that there was not a significant effect of music training on reading fluency, especially when controlling for other possible third variables such as cognitive abilities and socio economic status. In a recent study by Swaminathan, Schellenberg, &Venkatesan (2018) they argue that association between music training and reading may only be found when testing at low level reading abilities such as the level of phoneme awareness. The findings reported in this paper are consistent with the results of of Swaminathan et al., (2018) because they also found no effect of music training.

This study also aimed to establish appropriate measures for measuring musical perception in children, something that has not yet been well established in past research. All musical measures showed correlations with at least one of the other musical tasks. The mini-PROMS subtasks were all found to be correlated with at least one of each other subtask, which an indicator of good validity. However, the intercorrelations in this study were not as strong as previously reported in past investigation by Zentner and Strauss (2017). They report moderate to strong correlations between the measures (ranging from *r*=.23-.72). However our results show weak correlations between the subtests (*r*-.10-.31). It should be noted that Zentner and Strauss (2017) was validated on an adult population, so this could mean that the use of the mini-PROMS in child populations remains questionable in terms of validity. Also the mini-PROMS and BAT did not show any correlation with months of musical training, which implies questionable validity. Ideally, a strong musical perception task should show at least a moderate correlation with training, because experience with training in perceptual processes should inevitably improve scores. Strauss & Zentner (2017) found the mini-PROMS was moderately correlated with music training (*r=.42)* however our results do not support this, *(r=.17).*The task should also show a correlation with age, as a reflection that older children have more experience with tests and perception and should perform better..

It is possible the reason for weak correlations in the miniPROMS scores could be that they are quite repetitive and lack any visual components (other than the diagram indicating when to listen and when to compare). However, the means found in this study did not differ significantly from the means calculated on the previous study on adults (Zentner & Strauss, 2017). This is further evidence that the validity of the task may be questionable because the mean performance is the same but the correlations between music training and intercorrelations between the subtests themselves are weak. It could be argued the mini-PROMS has adequate reliability but poor external validity.

This study was limited in its sample due to a lack of returned parent questionnaires. Of the 120 children tested, only 81 questionnaires were returned, which led to a large amount of unusable data. In addition to that problem, many of the children in the sample did not have music training. Of the 81 usable questionnaires, 24 of the children had music training. Future research should specifically recruit musically trained populations, such as those from music schools or bands and choir groups. Also, parent questionnaires included with consent forms may lead to a higher amount of returned questionnaires. Despite these limitations, we did have a relatively large sample size even with n=81, which provides adequate power to reveal effects.

Overall, the results of this study indicate that music perception is related to reading in terms of tuning and speed awareness. This provides evidence for temporal and pitch theories that have been discussed in previous research. Therefore, it could be concluded from these results that the relationship between music and reading does have a more general relationship between basic perceptual processes such as pitch and tempo awareness, as opposed to more specific relationships that have been proposed in past research. Future research should examine the present question with modified mini-PROMS measures, perhaps by incorporating more realistic musical stimuli into the tasks. The re-evaluation of the musical stimuli to ensure high external validity may improve correlations between the mini-PROMS scores and music training. Once a well established and standardized music perception measure is in place, research will be better equipped to determine the nature of the relationship between music and reading.

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Appendix A

Descriptive Statistics

Table 1. Descriptive statistics. This table displays the descriptive statistics for the mean scores on each task participants completed.

Descriptive Statistics

Measure	N	Mean	Standard Deviation
Beat Apperception Task	119	14.70	9.06
Speed Subtask	120	4.38	1.46
Melody Subtask	120	5.38	1.71
Tuning Subtask	120	4.63	1.42
Accent Subtask	120	5.26	1.46
Total Months of Music Training	79	8.28	16.63
Hours Reading	81	5.06	5.11
Word Reading Subtest	120	105.57	16.61
Spelling Subtest	120	104.63	17.12
Vocabulary Test (PPVT)	120	114.50	13.95

Appendix B

Simple Correlations

Table 2. Simple correlations among predictor variables**.**

Predictor Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	-	.40	.340**	.050	.359**	.478**	-.014	-.086	.249*	-.236*	-.451**	-.513	.130	-.135
2. PPVT		-	.248*	.248**	.008	.048	-.202	.228*	.250	-.077	-.042	-.103	.209	.295**
3. Music Training			-	.192	.150	.086	.018	.110	.210	-.063	-.006	.125	.097	.239*
4. Tuning				-	.178	.125	-.107	.126	-.091	-.067	.031	.150	.047	.101
5. Speed					-	.217*	.038	-.142	.061	.091	-.151	.105	.105	.067
6. BAT						-	-.050	-.122	-.147	-.159	-.136	-.124	.055	-.146
7. Family Income							-	.473**	-.144	-.139	.109	.229	-.105	-.141
8. Av. Education								-	.052	.014	-.142	-.029	.017	.043
9. Hours Reading									-	.038	-.013	-.035	.153	.245*
10. Extraversion										-	.193	.201	-.012	.257*
11. Agreeableness											-	.299**	-.258*	.293**
12. Conscientious												-	-.019	.339**
13. Neuroticism													-	.264*
14. Openness														-

* significant at 0.05 level

**significant at 0.01 level

Appendix 3

Hierarchal Regression

Table 3. Results from hierarchal multiple regression.

Predictor	**Partial Correlation *(pr)***	***p*-Value**
Step 1: *R= .424, F(1,118)= 25.819, p = .000*		
PPVT	.424	.000
Step 2: *R= .514, F(2,116)= 14.434, p=.002*		
PPVT	.390	.000
Tuning	.204	.026
Speed	.219	.017