Composing literacy:
Exploring how musical aptitude explains technical reading abilities

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10.10.2020

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Master's thesis, pp. 31
Psychology
(October 2020)

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Abstract

Several studies have indicated a connection between musical skills and reading-related abilities. However, the underlying reasons to the connection have been unclear. I studied whether subskills within musical aptitude can explain the relationship between music and reading in 8–11-year-old children (N = 66). The children were tested for musical aptitude subskills: pitch discrimination, temporal discrimination, and tonal memory. The focus lay on technical reading abilities, namely performance in reading fluency and sentence comprehension in the Finnish primary school reading test. Linear regression models were used to assess whether the subskills, both together and separately, account for the variance in reading performance. The combination of musical aptitude subskills was related to technical reading abilities. Independently of other subskills, tonal memory explained both reading fluency and sentence comprehension while pitch discrimination explained only reading fluency. The findings support the hypothesis that musical aptitude and reading-related abilities share common mechanisms, such as pitch perception. More extensive research on how musical aptitude and reading are related is needed. Information about the underlying mechanisms in them could be used to create music interventions to support reading acquisition.

Keywords: music, musical aptitude, reading, reading fluency, sentence comprehension

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1. Introduction

Music occupies a substantial part in many people's lives, both intentionally and inadvertently. Apart from explicitly musical activities, such as playing an instrument or going to a concert, music is present practically everywhere in television series, advertisements, and shopping centres. Exposure to music begins already in early childhood because parents may listen to music at home or bring their children to public places where music is played in the background. In childhood, musical exposure is often interactive and spontaneous, for example when parents sing lullabies and sing-along tunes play on children's television shows. The extensiveness of musical exposure and musical interaction in childhood raises the questions of whether and how music affects the development of non-musical skills. Furthermore, as some musical abilities are suggested to be inborn (Arbib, 2013; Bigand & Poulin-Charronnat, 2006), they might alter or mediate the effects of musical exposure. Therefore, innate musical abilities could provide a medium to study how and why naturally occurring musical exposure may affect non-musical development.

The role of innate musical abilities in children's cognitive development and academic performance has been of special interest. For example, evidence for the association between musicality and performance in cognitive ability tests has been provided (e.g. Schellenberg, 2011; Swaminathan et al., 2017). As academic performance relies greatly on reading skills, an assessment of the connections between musical aptitude and reading skills has proved to be fruitful. Indeed, musicality or musical skills have been found to relate to reading development and reading-related skills, such as phonological skills (e.g. Anvari et al., 2002; Gordon et al., 2015). In other words, musical aptitude may influence how reading-related skills are acquired.

Reading skills are important not only in academic environments but also for navigating a Western society, because most of the publicly distributed information is in written form. If one cannot read, there is a greater risk to become marginalised, because using public services and seeking help usually requires the ability to understand written instructions. Due to the practically inescapable requirement to read, it is beneficial to study contributing factors to reading development to gain a more comprehensive understanding of reading acquisition. In the present thesis, I will examine the relationship between musical aptitude and reading skills in Finnish-speaking children.

1.1. Musicality

Musicality is defined in several ways depending on the purpose and the underlying theoretical presumptions about the constituents of musicality. Musicality can be used as an umbrella term for musical skills, talents, or aptitude. A key distinction to be held in mind throughout the whole thesis is between the terms musically trained and musically talented or apt. Musical talent and aptitude are associated to inborn abilities while being musically trained means having formal extra-curricular music instruction background. In other words, musical training leads to the acquisition of more advanced musical skills.

In contrast to acquired musical skills, Arbib (2013) defines musicality as a quality humans are born with. There are music-related abilities and capacities Western people have regardless of the amount of music training (Bigand & Poulin-Charronnat, 2006). For example, a Western listener would be able to differentiate a musical theme (a recurring piece of melody within a composition) from its variations and recognise harmonic tensions (deviations from harmony) and their releases back into harmony. The definition of musicality as an innate quality aligns with the synonymical terms musical talent and musical aptitude that refer to innate abilities. Hereafter, I will use the term musical aptitude to distinguish innate musical abilities from learned musical skills.

Musical aptitude has been described and tested in multiple ways. One of the most established tests is the Seashore Measures of Musical Talents (Seashore et al., 1956), hereafter the Seashore test, in which musical aptitude is divided into six subskills. The subskills and their corresponding subtests in the Seashore test are Pitch, Loudness, Rhythm, Time, Timbre, and Tonal Memory. Each of them measures accuracy in discriminating different aspects of auditory stimuli. For example, in the Pitch subtest, the participant determines whether the second pitch is higher or lower than the first pitch, and similarly in the Time subtest whether the second tone is longer or shorter in duration than the first. Also, auditory working memory capacity for short sequences of tones is measured with the Tonal Memory, where participants are required to indicate the deviating tone between two similar sequences. Since the aim of the present thesis is to study the role of components of musical aptitude in reading skills, a selection of Seashore subtests was used to measure musical aptitude. The selected subtests were Pitch for pitch discrimination, Time for temporal discrimination, and Tonal Memory.

1.2. Reading Acquisition in Children

Reading is a complex skill that requires multiple capabilities and mechanisms, such as visual processing, working memory, phonological awareness, and knowledge of writing system (Ehri, 2014; Rack et al., 1993, in Ehri, 2005). There are several stage or phase theories about the development of reading abilities in children. One theory presents that children initially pair printed and spoken words with the help of visual cues and later learn to decode (Gough & Hillinger, 1980). In another theory it is argued that there are four stages in changing reading strategy based on children's cognitive development (Marsh et al., 1981, in Stuart & Coltheart, 1988). Moreover, Frith (1985, in Stuart & Coltheart, 1988) proposes that there are three phases, each of which manifests a different word reading strategy. Despite the differences, most of the developmental reading theories include, in one form or another, the phases of **pre-reading**, **early reading**, **decoding**, and **fluent reading**, according to Ehri's (2005) review of reading acquisition theories. Here, I present only Ehri's phase theory of sight word reading and the process of orthographic mapping as they sufficiently cover the technical aspect of reading, which is the focus of my thesis.

Ehri (2005) proposes a theory of reading sight words, namely words that are read automatically from memory. The four phases in Ehri's (2005) theory of the development of sight word reading are pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic phase. These phases correspond with the aforementioned general phases pre-reading, early reading, decoding, and fluent reading, respectively. The **pre-alphabetic** phase (pre-reading) is characterised by contextual and visuographic cue reading. Contextual cues are images surrounding the text, such as logos. Logos are prominent in children's daily lives from morning cereal boxes to fast food chain advertisements, and children learn to associate brand names with their corresponding logos. Visuographic cues, in turn, are non-phonetic mnemonics related to the visual features of the letters. For example, the branches of "t" combined with two circular shapes "ee" may help a child remember what the print "tree" stands for without knowing how to read. Contextual images may facilitate faster reading or word recognition, but Ehri (2005) argues that they may be problematic because they are more salient than letters as cues.

For the efficient use of letters as cues, phonemic awareness is needed and it develops further during the pre-alphabetic phase. **Phonemic awareness** refers to separating and combining **phonemes**, which are the individual constituent sounds of words and the sounds of letters, as defined by Jones et al. (2009). In previous literature, phonemic awareness has sometimes been used interchangeably with phonological awareness, which Jones et al. (2009) define as the "ability to manipulate and discriminate sounds in syllables and words." However, phonemic awareness is a more detailed ability under phonological awareness, the former concerning the smallest units in words and the latter regarding units in speech in general.

In the context of sight word reading, phonemic awareness is crucial in learning grapheme-phoneme, i.e. letter-sound, correspondences. In each correspondence, one sound (phoneme) is linked to its spelling, such as "m" and "ng", to form a graphophonemic unit. By the time of transitioning to the second phase, **partial alphabetic** (early reading), an aspiring reader has learned at least some letter-sound correspondences and letter names. Ehri (2005) calls the phase "partial alphabetic" because a child might read a word by identifying the first and last letter and their corresponding sounds. For example the word "jam" could be recognised by the sounds of letters "j" and "m". In this phase, mistakes happen frequently because of confusing a word with another similarly spelled word.

The amount of such mistakes decreases with the increased knowledge of letter-sound correspondences. In the third, **full alphabetic** (decoding) phase, a child knows all or most letters and letter-sound correspondences in the alphabet of the language used in teaching. This knowledge is reached with the help of improved phonemic awareness because the ability to segment phonemes forms the foundation for finding letter-sound correspondences. Knowledge of correspondences in turn is crucial in decoding words. In the full alphabetic phase, a child decodes a word by identifying all the letters and their sounds and by combining the sounds to form a comprehensible word. According to Ehri (2005), the vocabulary of sight words grows exponentially, as the child becomes better at decoding.

In the fourth, **consolidated alphabetic** (fluent) phase, the reader maintains the vocabulary of sight words efficiently with morphographic connections (Ehri, 2005). While phonemes are simply the smallest language units, morphemes are the smallest units that carry a meaning, for example in "unbreakable": prefix un-, root word -break-, and suffix -able. Morphographic connections link morphemes with their written form, the spelling, and these written forms of morphemes are called letter sequences here. Knowledge of letter sequences makes reading faster, effortless, and more automatic by enhancing the ability to decode. Decoding happens not only letter by letter anymore, but also through letter sequences. To summarise, the process of learning to read starts from the context in the pre-reading phase, delves into the details in the early reading and decoding phases, and resurfaces in the fluent phase to a larger view with an implicit comprehensive understanding of the fundamental constituents of the text.

In addition, Ehri (2014) provides a description of orthographic mapping, which is an important process during sight word reading. Orthographic mapping is a process of connecting letters to sounds, binding spellings, pronunciations, and semantics in memory (Ehri, 2014). Orthographic mapping is activated when reading novel words or pseudo-words, which are non-existing words that are similar to real words. Furthermore, orthographic mapping is a multisensory process including visual, auditory, and motor skills for perceiving and producing correct spelling and pronunciation. Thus, the detailed process of fluent reading involves a complex network of connections that collaborate smoothly.

1.3. Cognitive Abilities Behind Reading

1.3.1. Language Comprehension

First and foremost, as a skill dependent on language, the cognitive basis of literacy is language comprehension. According to the Cognitive Foundations Framework by Tunmer and Hoover (2019), language comprehension comprises of **phonology, semantics, and syntax**. **Phonological skills** include speech perception mechanism and word recognition. Accurate speech perception relies on auditory processing to perceive and distinguish speech from background noise. Accuracy is integral to successful speech perception as it allows the segmentation and decoding of speech sounds that facilitate word recognition. If even a single speech sound unit, phoneme, is misheard, it could result in a misunderstanding, for example “fan” versus “van”. Word recognition is followed by the activation of **semantic skills**, which give meaning to the recognised words by retrieving semantic information about the words from mental lexicon. The mental lexicon is like a dictionary stored in memory, including the literal meanings of words and information about the connections between related words.

However, simply knowing the meaning of each word is not enough to understand a whole sentence. Syntax is the feature that structures and organises language, and this is where **syntactic skills** step in to make sense of a sequence of utterances with knowledge of word order, parsing, and verbal working memory capacities (Tunmer & Hoover, 2019). Word order is important in Germanic languages like English and Swedish to differentiate who did what to whom (“the dog bit the cat” versus “the cat bit the dog”), which is why knowledge of the functions of words and relations between them is essential in language comprehension. Parsing, in turn, is applying word order and semantic knowledge and arranging the words hierarchically to derive meaning from the sequence of utterances as a whole. Such complex language processing requires verbal working memory and seamless cooperation of linguistic processing units.

Although the linguistic processes are presented sequentially here, they actually happen parallel to each other in an interconnected manner. Tunmer and Hoover (2019) explain that slow parsing would cause missing parts of the information of the sentence and slow word recognition would lead to forgetting the beginning of the sentence. Tunmer and Hoover (2019) also remind that because the capacities of working memory are limited, parsing needs to happen swiftly and word recognition as automatically as possible in order to comprehend language efficiently and accurately.

The linguistic knowledge described above accounts for comprehension of the literal meanings of words and sentences, and naturally there is more to language comprehension than literal meaning. Exposure to language, social interactions with conversations, and explicit linguistic instruction by parents or teachers make it possible to understand that when it “rains cats and dogs,” it refers to heavy rain, not four-legged house pets pouring down from the sky. Tunmer and Hoover (2019) highlight the importance of possessing background knowledge for context to deduce the intended meaning of a sentence. Background knowledge can be obtained through life experience and provided by parents, teachers, instructors, or other people in social encounters. As Tunmer and Hoover (2019) point out, relevant background knowledge enhances the powers of deduction on language comprehension.

1.3.2. Perceptual and Cognitive Processes Behind Reading

Understanding language lays a foundation to learning to read, and many of the processes involved in language and reading are highly inter-related. For example, without accurate auditory perception, phonological skills cannot be utilised for the categorical perception of speech to differentiate syllables and phonemes (McArthur & Castles, 2017; Pezzino et al., 2019). Furthermore, word recognition suffers greatly from poor phonological skills, and slow word recognition in turn hinders the growth of mental lexicon. As Pezzino et al. (2019) describe, hindrances in oral language development may cause a vicious circle where slow lexical development leads to reading less and having a smaller lexicon because of being less exposed to novel words.

Visual and auditory perception abilities are also interconnected in reading. Visual perception abilities are crucial in learning letters and processing units larger than letters, such as syllables and whole words (McArthur & Castles, 2017). Successful differentiation of syllables and phonemes with accurate auditory perception develops orthographic mapping in terms of pronunciation and letter-sound correspondences. The formation of these correspondences is also facilitated by the ability to combine visual (letter combination "CH") and auditory information (sound "ch"). Functional visual attention, in turn, is needed to detect small orthographic units so that they can be added to the orthographic mapping and utilised in reading novel words. For instance, knowing the syllable "diff" from the word "difficult" and having the syllable in one's orthographic mapping helps reading the words "differ" and "different".

Moreover, oral language development relates to reading by means of word recognition and automatised syntax processing (Pezzino et al. 2019). When these processes are quick, the load on working memory is lighter and the reader can focus on comprehending the text, similarly to successful speech comprehension described in section *1.3.1. Language Comprehension*. Also, mental lexicon, a domain within oral language development, is essential in reading because it contains semantic (McArthur & Castles, 2017) and orthographic information of words. Fluent reading requires the ability to retrieve and use orthographic units stored in the mental lexicon (Pezzino et al., 2019).

Executive functions also play a significant role in reading. Executive functions as cognitive abilities are to other reading-related skills what teachers are to students; they distribute tasks, set boundaries, tell what to focus on, and show the bigger picture. Theoretically, executive functions lead to successful reading comprehension by maintaining relevant and suppressing irrelevant information in working memory, adjusting attention, and integrating information (Butterfuss & Kendeou, 2018). Executive functions contribute to reading acquisition already in kindergarteners. Foy and Mann (2013) demonstrate that especially verbal inhibitory executive functions are correlated with early reading skills, such as phonemic awareness, letter name knowledge, and reading words and pseudo-words.

Working memory, here specifically auditory working memory, belongs to executive functions (Miyake et al., 2000), and it is the most relevant part of executive functions regarding the studied music and reading variables in the present thesis. Working memory is a system of limited capacity to store task-relevant information (Spillers, et al., 2012). The purpose of the working memory is to keep information active during the time it is processed for the task at hand. Working memory is needed while reading (Pezzino et al., 2019), and auditory working memory is recognised as a contributing factor to literacy acquisition (Tierney & Kraus, 2013). Auditory working memory is important in phonological processing, which facilitates reading development, because it allows for keeping sequences of sounds in mind long enough so that they can be decoded as linguistic units, such as phonemes (Tierney & Kraus, 2013). Auditory working memory is relevant not only for aspiring readers but also for skilled readers, because it is one of the several factors that explain reading fluency (Foncubierta et al., 2020).

1.4. Common Components in Language, Reading, and Music

1.4.1. Language and Music

The connection between language and music may best be revealed in speech, because of brain mechanisms that underlie both speech and music (Jones et al., 2009; Strait et al., 2011), such as pitch perception. Because music training has been found to improve pitch perception (Bolduc, 2009), it may even support oral language comprehension through enhanced pitch discrimination skills (Thompson et al., 2004). Evidence for musical pitch perception skills correlating with phonological skills (Forgeard et al., 2008) awakens interest in the possibility that music has a transfer effect to language skills in general. In that case, musical aptitude could be the underlying reason to why music training or musical exposure affects language development.

Intentional musical exposure has been proposed to have causal links to language-related skills, which has been tested with intervention studies. For example, positive causal effects of a music programme include increased vocabulary (Linnavalli et al., 2018) and improved phonological skills in kindergarteners (Bolduc, 2009; Linnavalli et al., 2018). Music training is proposed to enhance children's general learning readiness, which in turn could further oral language skills (Partanen & Virtala, 2014). Intuitively speaking, the long-term goal-oriented and systematic nature of music training would be expected to positively affect learning readiness. Also, because music training enhances auditory perception skills, these effects are hypothesised to be seen in prosody perception and speech production (Partanen & Virtala, 2014). Because musical activities usually include social interaction, which is a crucial part of language development, Partanen and Virtala point out the possibility that several mechanisms mediate effects from music training to language.

Furthermore, speech-in-noise perception is an aspect of oral language skills that touches musical abilities. Pitch discrimination is needed to filter speech frequencies from background noise frequencies. The enhanced effects of music training on pitch discrimination accuracy have been demonstrated (Nan et al., 2018, Wong et al., 2007), and these effects have been observed to transfer to accurate speech-in-noise perception in children treated for hearing impairment with cochlear implants (Torppa et al., 2018). Similar training effects have also been observed in normally hearing children speaking Mandarin (Nan et al., 2018), a tonal language, where pitch is relevant in recognising words. Thus, accurate pitch discrimination helps hearing speech in noisy environments.

In addition to being relevant in speech-in-noise perception and speech perception in tonal languages, pitch also plays a role in non-tonal languages, like English and Finnish. Pitch is one of the components in prosody, which is a specific feature of spoken language and appears to be comparable to music. For example, prosody occurs in speech as raised intonation at the end of a question and as high speed with a loud voice to express urgency. Thus, both prosody and music demonstrate variations at least in pitch, speed, and loudness. As Patel and Iversen (2007) note, pitch discrimination is important not only in music but also in the nuanced comprehension of speech. Improved pitch perception with the help of music training could have facilitating effects in decoding speech prosody, which in turn aids speech comprehension (Thompson et al., 2004). These results on the connections between music training or musical aptitude, pitch encoding, and speech perception provide further evidence for overlap in music and language skills.

A theoretical kind of overlap in music and language could be seen in the generation of musical anticipations, one of the natural musical abilities recognised by Bigand and Poulin-Charronnat (2006). Generating musical anticipations is understandable because of musical conventions. These conventions are the reason to the similarities in the way that themes, variations, tensions, and releases are presented in musical pieces. Musical conventions, including music theory, can be compared to the grammar of language. In language, we have grammar rules that organise the way we use words and combine them. These rules combined with a given context allow a listener to anticipate what the speaker will say and how they will convey their message. If a speaker presents a question, a listener will anticipate an answer, in the same way when a listener perceives musical tension and expects a release. Parallels could be drawn further, with a single musical note comparing to a phoneme, a small combination of notes to a word, a musical phrase to a sentence, or a verse to a chapter. Because of the parallels between musical structure and grammar of language, it is not entirely surprising that abilities in perceiving musical rhythm have been found to correlate with grammar skill differences in children (Gordon et al., 2014).

1.4.2. Reading and Music

Evidence for the relationship between reading and musical aptitude or music training has accumulated. Capacities and subskills proposed to underlie the correlational relationship include intelligence, auditory processing, phonological skills, pitch processing, and rhythm skills (Pezzino et al., 2019, Tierney & Kraus, 2013). There is constant debate on whether pre-existing differences in innate abilities predispose cognitively high-performing children to choose music lessons (Schellenberg, 2011; Swaminathan et al., 2017). In a study discovering a strong link between music training and reading comprehension, a high correlation between reading skills and intelligence measured with cognitive ability tests was also found (Corrigall & Trainor, 2011). If the premise of predisposition to engage in musical activities holds, one would naturally find strong links between music training and reading comprehension. However, Corrigall and Trainor (2011) explain that this premise cannot fully account for their results because the association between music training and reading comprehension became robust only after accounting for intelligence, socio-economic status, and age. Still, there is room for debate about whether the interplay between intelligence and musical aptitude, rather than intelligence alone, explains the connection between reading and music training.

In addition to intelligence, the role of the auditory domain is a recurring and prominent theme in studies on music and reading. Strait et al. (2011) uncovered a relationship between auditory working memory and attention and music aptitude in children regardless of the amount of music training. They suggest that their results point to common mechanisms in processing auditory regularities that are fundamental to musical and reading abilities. After all, skills related to both music and reading rely on auditory processing abilities (Corrigall & Trainor, 2011). At least, there is behavioural evidence that speech and music perception share pitch processing mechanisms (e.g. Bidelman et al., 2011; Magne et al., 2006; Peretz et al., 2015). It is common to pronounce text internally while reading, a feature related to inner speech, so auditory input from reading comes from internal sources. In fact, including musical aptitude in the acoustic part of reading explains silent reading fluency in adults (Foncubierta et al., 2020). Thus, assuming that auditory processing of music and language overlap, musical aptitude could indeed relate to the auditory processes of silent reading.

Reflecting further on auditory skills, rhythm is being studied in increasing amounts as a uniting feature between music and reading. Rhythm skills are linked to reading development and, more specifically, to phonological skills in children (Bhide et al., 2013; Holliman et al., 2010; Moritz et al., 2013). Children's phonological skills can even be improved with music training (Moritz et al., 2013) that focuses on rhythm (Bhide et al., 2013). Moritz et al. (2013) propose that rhythm sensitivity precedes spoken language learning and that early rhythm skills may link phonological and more developed rhythm skills. Therefore, rhythm could function as a binding component between music and reading-related skills.

The role of rhythm connecting music and reading does not seem straightforward at first, because rhythm is present in music and language in different ways, with music having beat-based (regular) and speech having non-beat-based (irregular) rhythmic patterns (Ozernov-Palchik & Patel, 2018). Although music and speech have different kinds of rhythms, the relationship between rhythmic processing abilities and early reading skills could be explained with time-related processing mechanisms shared by music and speech (Ozernov-Palchik & Patel, 2018). These shared mechanisms may explain why rhythm skills predict the level of reading-related skills in children (Lundetræ & Thomson, 2018; Ozernov-Palchik, Wolf & Patel, 2018). In sum, time-related processing alongside pitch processing in musical aptitude may contribute to reading.

1.5. Research Questions

In this thesis, I will explore the relationship between musical aptitude measured with a selection of Seashore subtests and technical reading skills in children. Here, the technical reading skills of interest are reading fluency and sentence comprehension that are measured with technical reading subtests from a Finnish reading test for primary school children, Ala-asteen lukutesti (ALLU, Lindeman, 1998). The premise behind the hypothesised relationship is the overlap between music and cognitive skills for which previous literature provides evidence.

My research questions are as follows:

1. How much of the variance in reading fluency and sentence comprehension does musical aptitude test performance explain?

2. Do test performances in pitch discrimination, temporal discrimination, and tonal memory have unique explanatory power in the variance in reading fluency and sentence comprehension?

2. Methods

2.1. Participants

The participants were Finnish speaking children aged 8–11 (M = 9.66, SD = 0.51) from primary schools in Southern Finland. In total, 70 children participated, but four children were excluded from the statistical analyses because of missing test results due to the children's absences. The research was approved by the Ethics Committee for Human Sciences, University of Turku. The criteria for participating were the child's normal hearing and neurotypicality, as in the lack of neurological or neuropsychological diagnoses. All children willing to participate and their parents gave their informed consent. Introduction letters about the research and consent forms were given at school to children who delivered the forms home to be signed by parents.

2.2. Measures

2.2.1. Language Comprehension and Technical Reading Abilities

The children's language abilities were tested with the subtests for Verbal Comprehension Index (VCI) of Wechsler Intelligence Scale for Children (WISC-IV, Wechsler, 2003). VCI measures language abilities that do not rely on reading skills, such as explaining similarities between two concepts (Q: "What do yellow and blue have in common?" A: "They are colours."). The children were tested with all three core subtests, Comprehension, Similarities, and Vocabulary, and one supplemental subtest, Information. In the Comprehension subtest the child is required to provide answers to complex questions about different situations, for example "Why do children go to school?". The Vocabulary subtest measures the child's ability to define words, and the Information subtest measures general knowledge, such as who was the first female president in Finland. Here, VCI was used to account for the effect of language abilities in reading performance.

Technical reading abilities were measured with two subtests from the standardised Finnish primary school reading test (Ala-asteen lukutesti, ALLU, Lindeman, 1998). The selected tests were Reading fluency and Sentence comprehension; both belonged to the technical reading section of the ALLU test battery. The Reading fluency subtest consisted of chains of two or three words written together without spaces (for example, bottlelamp or cathousephone). In the subtest, children separated the words by drawing vertical lines between them (bottle|lamp or cat|house|phone). In the Sentence comprehension subtest, each trial had an illustration to be paired with the corresponding sentence, which was one of the four alternatives presented with the illustration. Technical reading abilities were also measured with a pseudo-word reading task based on Finnish phonology (Service, 1989), but it was eliminated from the analyses due to a ceiling effect.

2.2.2. Musical Aptitude

Musical aptitude was assessed with Seashore Measures of Musical Talent (Seashore test, Seashore et al., 1956) because it is a widely used and functional test for components of musical aptitude (Milovanov, 2009). Only three out of six subtests in the Seashore test were selected because of limited testing times. The selected subtests measure the ability to discriminate pitch (Pitch) and tone duration (temporal discrimination, Time) of individually presented sound stimuli, and differentiate deviations in melodies (Tonal Memory). Pitch and Tonal Memory were chosen as they were related to phonemic skills (Milovanov, 2009). Also, Time was chosen because of the relevance of sound length in double vowels and consonants in the Finnish language: takka, taakka, and taka all have different meanings.

In the Pitch subtest, 50 pairs of pitches were presented and the children were asked to discriminate whether the second pitch was higher or lower than the first. In the Time subtest, 50 pairs of tones of varied lengths were presented and the children determined whether the second was longer or shorter than the first. The Tonal Memory subtest had 30 pairs of short melodies consisting of three to five tones. The second melody of each pair deviated from the first by one tone and the children indicated the deviating tone by circling its corresponding ordinal number. The raw scores were standardised per the Seashore manual instructions (Seashore et al., 1960) into percentages, which were used to calculate a mean score of the three subtest scores for every participant (Viitanen, 2012).

Musical abilities were also measured with the Scale test from the Montreal Battery for the Evaluation of Amusia (MBEA, Peretz et al., 2003) to test the accuracy of processing sounds in a musical context. It was eliminated due to significant correlations with the Seashore subtests Pitch ($r = .40$) and Tonal Memory ($r = .63$) and a different theoretical standpoint compared to the Seashore test. MBEA focuses on screening for amusia, which is a neurological disability to process musical components (Vuvan et al., 2018), while the Seashore test focuses on differentiating areas of musical aptitude.

2.3. Procedures

The data were collected in 2010 and 2011 in Southern Finnish primary schools. The children were tested individually in quiet rooms during school days by Kivimäki and research assistants, who were psychology students. The assistants tested the children with all the other tests except for musical aptitude, which was measured by Kivimäki. All of the tests had instruction and practice rounds before presenting the actual test. The recorded instructions for the Seashore tests were in English, so Kivimäki translated the instructions to Finnish. Kivimäki used a small synthesiser to demonstrate how the test stimuli would be presented and to instruct that the children should base their answer on how the latter stimulus differed from the former one.

2.4. Statistical Analyses

The research question about how much of the variance in the measured reading skills can music aptitude test performances explain was explored by generating linear regression models. I used the Seashore mean score to examine whether music aptitude in general can explain reading performance. To further analyse the unique explanatory power of each music aptitude subtest performance, the scores of the three subtests were included in the models separately instead of the mean scores. Thus, I created two linear regression models with mean scores and subtest scores separately – henceforth Mean model and Separate model, respectively – for both of the dependent variables, reading fluency and sentence comprehension. The analyses were performed on SPSS using the backward stepwise approach.

The dependent variables were Reading fluency and Sentence comprehension and the independent variables were VCI, three Seashore subtests Pitch, Time, and Tonal Memory, and Seashore Mean score of the subtests. Tests for collinearity of the data were run for each regression model. The goodness of fit of each model was assessed with Akaike Information Criterion (AIC), where the smaller value among the compared models indicates a better fit.

3. Results

The results from linear regression analyses showed that VCI and Seashore test scores explained technical reading performance in children. Performance in the subtest Pitch accounted independently for variance in reading fluency scores, while Tonal Memory explained variance in both reading fluency and sentence comprehension scores uniquely. Both Mean and Separate models fit the data fairly well.

3.1. Reading Fluency

The linear regression models in both Mean and Separate setting fit the data, $F(2,64) = 21.89$, $p < .001$, adjusted $R^2 = .39$, and $F(3,63) = 14.04$, $p < .001$, adjusted $R^2 = .37$, respectively. Thus, VCI and Seashore scores accounted for nearly 40% of the variance in the reading fluency scores, both in Mean and Separate models. Multicollinearity did not cause problems in the Mean model (VCI: Tolerance = .98, VIF = 1.02; Mean: Tolerance = .98; VIF = 1.02) or in the Separate model (VCI: Tolerance = .97, VIF = 1.03; Pitch: Tolerance = .59, VIF = 1.71; Tonal Memory: Tolerance = .59, VIF = 1.70).

The descriptive values of each variable and the AIC values of the linear regression models for reading fluency are presented in Table 1. The AIC analysis implies that the Mean model fits the data better than the Separate model, with 641.85 versus 644.48, respectively. In the Mean model, both the VCI and Seashore mean scores explain the variance in reading fluency. In the Separate model, the Seashore task Time was excluded from the final model. Interpreting from the β-values, VCI explains basically the same amount of variance in reading fluency scores in the Mean and Separate models. Based on the β-values, the Seashore task Pitch ($\beta = .25$) plays a recognisable role in explaining reading fluency, but the role of Tonal Memory ($\beta = .38$) is larger.

Table 1. Two linear regression models of the relation of verbal cognitive capacity (VCI) and musical aptitude to reading fluency.

Model	AIC	Variable	B	CI95%	SE	β	t	p
Mean	641.85	Constant	-14.31	[-60.76, 32.13]	23.25		-0.62	.540
		VCI	0.45	[0.01, 0.89]	0.22	.20	2.05	.045
		Mean	0.85	[0.56, 1.13]	0.14	.58	5.92	< .001
Separate	644.48	Constant	-2.82	[-49.26, 43.62]	23.24		-0.12	.904
		VCI	0.44	[-0.01, 0.88]	0.22	.19	1.95	.056
		Pitch	0.30	[-0.01, 0.61]	0.16	.25	1.92	.059
		Tonal Memory	0.42	[0.14, 0.70]	0.14	.38	3.03	.004

3.2. Sentence Comprehension

Both models Mean and Separate explained variance in reading, $F(2,63) = 10.59$, $p < .001$, adjusted $R^2 = .23$, and $F(2,63) = 11.79$, $p < .001$, adjusted $R^2 = .25$, respectively. More explicitly, Seashore scores together with VCI explained approximately a quarter of the variance in reading comprehension scores in both settings. Multicollinearity was not an issue in the Mean model (VCI: Tolerance = .98, VIF = 1.03; Mean: Tolerance = .98, VIF = 1.03) or in the final Separate model (VCI: Tolerance = .98, VIF = 1.02; Tonal Memory: Tolerance = .98, VIF = 1.02).

Table 2 presents the contributions of each variable in the linear regression model regarding sentence comprehension and the AIC values. When explaining performance in sentence comprehension, the Separate model seems to be slightly more extensive than the Mean model, according to the AIC analysis, with values 313.42 versus 315.26, respectively.

In the Mean model, both the VCI and Seashore mean scores explains the variance in sentence comprehension. In the Separate model, the Seashore tasks Pitch and Time were excluded from the model with the backward stepwise method, leaving Tonal Memory in the final model. The descriptive values of VCI are very similar to the ones in the Mean model. Tonal Memory (β = .41) appears to explain the variance in sentence comprehension slightly more than Seashore mean scores (β = .38).

Table 2. Two linear regression models of the relation of verbal cognitive capacity (VCI) and musical aptitude to performance in sentence comprehension.

Model	AIC	Variable	B	CI95%	SE	β	t	p
Mean	315.26	Constant	4.64	[0.42, 8.86]	2.11		2.20	.032
		VCI	0.05	[0.01, 0.09]	0.02	.27	2.45	.017
		Mean	0.05	[0.02, 0.07]	0.01	.38	3.47	.001
Separate	313.42	Constant	5.28	[1.18, 9.39]	2.06		2.57	.013
		VCI	0.05	[0.01, 0.09]	0.02	.27	2.47	.016
		Tonal Memory	0.04	[0.02, 0.06]	0.01	.41	3.76	< .001

4. Discussion

The aim of the thesis was to explore the relationship between musical aptitude and reading. Children aged 8–11 years were tested for musical aptitude (Seashore test), technical reading abilities (ALLU), and verbal comprehension (VCI). Musical aptitude included a selection of subskills: pitch discrimination, temporal discrimination, and tonal memory. Technical reading abilities included reading fluency and sentence comprehension. The research questions were whether musical aptitude explains performance in reading tests and whether performance in each Seashore subtest relates uniquely to reading performance. With linear regression models, I explored to what extent musical aptitude, either subskills together or separately, explains reading fluency and sentence comprehension. The results in the present thesis indicate that musical aptitude explains both reading fluency and sentence comprehension in children. Furthermore, pitch discrimination and tonal memory explains reading fluency uniquely, but only tonal memory explains sentence comprehension independently of the measured subskills.

4.1. Main Findings

The first finding of this study was that the subskills pitch discrimination, temporal discrimination, and tonal memory together are related to reading fluency and sentence comprehension. The relationship between musical aptitude and reading discovered here could be explained with the hypothesis that common mechanisms in the auditory processing of musical and linguistic input underlie reading (Strait et al., 2011). For example, pitch perception and auditory working memory are relevant in both musical aptitude subskills and reading-related language skills. These mechanisms are discussed in more detail while evaluating the roles of pitch discrimination, temporal discrimination, and tonal memory in reading performance separately.

The second finding highlighted that two musical aptitude subskills were connected to technical reading skills independent of each other. Pitch discrimination was related to reading fluency, which could be explained with phonological skills. With phonological skills, constituents of speech can be segmented so that they can be encoded into letters, syllables, and words. As part of enhanced musical abilities, pitch discrimination skills are related to the development of phonological representations (Chobert et al., 2011). Specifically, pitch discrimination could be relevant in separating words in speech by helping to perceive the start of the next word, as the pronunciation of the next word may often start from a slightly different pitch than the previous. Once the words are separated, the constituents of words (syllables and phonemes) can also be recognised and used to create phonological representations of the words, which belong to the orthographic mapping that enables good reading ability (Ehri, 2014). In other words, the results of this study support the notion that pitch discrimination belongs to the particular domain of oral language development that is needed in reading.

The other musical aptitude subskill that had an independent connection to technical reading skills was tonal memory. It was linked to both of the measured technical reading skills, reading fluency and sentence comprehension. Tonal memory essentially combines pitch discrimination and auditory working memory since tone sequences must be kept in mind long enough to distinguish the deviant tone. Firstly, the pitch discrimination part of tonal memory may relate to sentence comprehension via oral language comprehension. As accurate pitch discrimination is needed in detecting speech prosody and thus understanding speech with all its subtleties (Patel & Iversen, 2007; Thompson et al., 2004), pitch discrimination supports the development of language comprehension generally. This interpretation would be in line with the results of pitch discrimination skills independent of music training being correlated with reading (Forgeard et al., 2008). Secondly, auditory working memory is recognised as one of the skills that underlie reading (Foncubierta et al., 2020; Tierney & Kraus, 2013), which could provide another reason to why tonal memory relates to both reading fluency and sentence comprehension. Both tonal memory and reading fluency, here as the quickness of recognising and separating words written together, require working memory in general. Specifically, auditory working memory may be needed in reading fluency especially if the word chains are pronounced internally to help with the word separation. Lastly, sentence comprehension also requires working memory to keep the beginning of the sentence in mind until reaching the end in order to process and understand the sentence as a whole.

The third measured musical aptitude subskill, temporal discrimination, did not explain reading fluency or sentence comprehension independently. The result is slightly unexpected due to previous findings about the link between rhythm and reading skills (Bhide et al., 2013; Holliman et al., 2010; Ozernov-Palchik et al., 2018). Temporal discrimination may be one of the underlying abilities behind rhythm perception because recognising differences in durations between tones ought to be part of perceiving rhythmic patterns. Temporal discrimination, in the way it was measured with the Seashore test, might as well belong to early rhythm skills, which Moritz et al. (2013) hypothesise to connect phonological skills and more advanced rhythm skills. The role of temporal discrimination is possibly seen in combination with pitch discrimination and tonal memory but taken separately it is not strong enough to explain technical reading performance.

Additionally, the Mean and Separate linear regression models served as a way to compare the differences in how much the selected musical aptitude subskills together (Mean) versus separately (Separate) explain variance in reading performance. The Mean model explained reading fluency better than the Separate model, but the roles were reversed when explaining sentence comprehension. The differences appeared to be relatively minor, so no conclusions can be drawn as to which model should be preferred when explaining both reading fluency and sentence comprehension.

4.2. General Discussion

Theoretically, the development of phonemic awareness could explain the results about the relationship between musical aptitude subskills and reading abilities. As pitch discrimination is related to both music and speech sounds (Jones et al., 2009), it could play a role in the development of phonemic awareness. Through phonemic awareness, the finding of pitch discrimination and tonal memory relating to reading fluency might have a connection to the way Ehri (2005) outlines the development of sight word reading. Phonemic awareness is important in learning letter-sound correspondences (Ehri, 2014; Tunmer & Hoover, 2019), an essential part of learning to read sight words. Reading fluency is connected to the level of sight word reading ability, and letter-sound correspondences and the repertoire of letter sequences (typically syllables) are relevant when reading sight words in Finnish. Letter-sound correspondences and syllables are easy to learn in the Finnish language because each letter usually has only one sound both individually and within different syllables, unlike in English where the letter "A" is pronounced differently in the one-syllable words "hat" and "car". Knowing syllables enables the reader to read larger units than individual letters at a time, which quickens the process of separating words in word chains. Successful learning of letter-sound correspondences and syllables is needed to reach the consolidated alphabetic phase, in which reading becomes more automatic (Ehri, 2005). Pitch discrimination could be relevant in learning both letter-sound correspondences and syllables, in case pitch discrimination is related to phonemic awareness. Auditory working memory in turn is needed to keep phonemes in mind to combine them with letters (Tierney & Kraus, 2013) and thus is also relevant in learning letter-sound correspondences. In sum, pitch discrimination and auditory working memory together may be linked, via phonemic awareness, to how fast or well each phase in the development of sight word reading is reached.

Practically, the value of the findings in the present thesis lies in providing more knowledge about the relationship between musical aptitude and reading. This study adds to previous literature of the relationships between music and reading (e.g. Anvari et al., 2002; Corrigall & Trainor, 2011; Huss et al., 2011), focusing on a selection of musical aptitude subskills and technical reading skills. The gained knowledge about the relations of pitch discrimination and tonal memory to reading abilities could be used to design better musical interventions to support literacy. At least, correlational evidence has been provided about the relationship between music training and reading-related skills (Corrigall & Trainor, 2011; Dittinger et al., 2017; Gordon et al., 2015). Also, because positive effects of musical interventions have been found in some linguistic skills, such as phonological skills, in kindergarteners (Bolduc, 2009; Linnavalli et al., 2018), extending the enhancing effects to reading acquisition is a possibility. For example, musical intervention focused on rhythmic training has been found to support reading acquisition and improve phonological skills in poorly reading children (Bhide et al., 2013). Even with typically developing children, focus could be directed to improving those musical aptitude subskills which are connected to reading-related skills, for example improving pitch discrimination to induce a transfer effect to phonological skills.

The discussion around supporting literacy with music may easily become complicated because of the intertwined roles of nature and nurture, where musical aptitude represents nature and music training represents nurture. Not only literacy, but also academic skills and cognitive abilities in general have been of interest regarding their connections to musicality. Positive correlations between musicality and cognitive abilities in previous literature give reason to suspect that specifically musical aptitude, not music training, lies behind the association (Swaminathan et al., 2017). Children who perform well in school and in cognitive ability tests may be predisposed to take music lessons in the sense that they have high musical aptitude that makes them interested in music. Thus, the combination of innate and gained musicality and good performance in school may create an illusion that music training enhances academic skills. Although the enhancing effects of music training on cognitive abilities and academic skills have not been confirmed in a recent meta-analysis (Sala & Gobet, 2020), the possibility remains that musical aptitude explains such effects.

The predisposition to seek musical activities complicates studying the effects of musical aptitude on reading and other academic skills. Musical activities, such as going to concerts and spontaneous singing with family among other musical interaction, may strengthen abilities that underlie both musical skills and academic skills. The musical background and socioeconomic status of the family can also amplify the possible impact of musical aptitude on non-musical skills. For example, if the family engages in spontaneous musical interaction and has the financial resources to offer explicit music training, the musical aptitude of the child will be further supported and reinforced. Consequently, children who have high musical aptitude and engage in musical activities have a higher chance of benefiting from explicit music training and experiencing possible transfer effects in reading-related skills.

In addition to musical aptitude, the pleasant, fun, and interactive nature of musical activities is worth noting as a contributing factor to the willingness of young children to engage in educational activities, as Standley and Hughes (1997) remind. Pleasantness and joyfulness motivate a child to learn and thus may mediate beneficial effects of music training. Dedication and commitment could explain the establishment of long-term effects of music training (Costa-Giomi, 1999). Costa-Giomi explains that enthusiasm about a new activity helps acquire new cognitive strategies for learning music and leads to initial improvement in cognitive abilities. Fading of enthusiasm, in turn, hinders the development of learning strategies, so continued cognitive benefits rely on a more conscious commitment. Instead of focusing on commitment to explicit music training, musical content could be used as an interactional, socially rewarding, and motivating element in teaching reading skills. If simple musical interaction could be incorporated into regular teaching to reinforce children's musical aptitude and improve learning motivation, children could benefit from their natural musicality despite the level of their musical aptitude. The modifying effect of socially rewarding musical interaction on motivation should not be underestimated in educational activities. Therefore, utilising children's innate musicality in supporting reading and other language-related skills ought to be considered.

4.3. Limitations

The limitations of this study must be considered before generalising the results. Firstly, the sample size is relatively small, with less than a hundred children. Secondly, the children's auditory working memory was not tested and tonal memory cannot be assumed to cover it. On the other hand, sufficient level of performance in auditory working memory could be speculated to facilitate tonal memory as long as the participant has some pitch discrimination skill. Therefore, tonal memory may adequately account for auditory working memory.

Thirdly, the children were not tested for other cognitive abilities than verbal comprehension. Nuances in the possible interplay of the level of cognitive abilities, reading skills, and musical aptitude may remain missing. However, this limitation may not have any practical relevance as none of the children was diagnosed with developmental problems so their performance in verbal comprehension can be assumed to reflect their overall cognitive abilities.

Lastly, the Western and Eurocentric approach to musicality cannot be ignored. Seashore's work was heavily affected by eugenics (Devaney, 2019) that was a trend in politics and science in the early 20th century. The simplicity of the musical stimuli in the Seashore test is argued to make the test exempt from racial biases, even though the theory behind the test is based on white Western music and Seashore's eugenic ideas. For example, Seashore presented in a eugenics congress that musical talent includes measurable innate qualities that can be used to study racial differences for "eugenic guidance" (Seashore, 1923, in Devaney, 2019). Seashore's work and cultural biases have also impacted the development of more recent musical test batteries (Devaney, 2019), such as the MBEA (Peretz et al., 2003). Nevertheless, because the children in the present study were all native Finnish speakers and thus can be assumed to have been socialised into a Western culture, the cultural biases do not pose a grave limitation to using the Seashore test on Western children. The underlying theoretical biases simply restrict the interpretation of the results to a Western or European context.

4.4. Conclusions and Further Research

Musical aptitude measured with performance in selected subskills was related to technical reading abilities, namely reading fluency and sentence comprehension, in children. Considering the subskills together, musical aptitude explained variance in both of the measured reading abilities. Examining the subskills separately, tonal memory played a distinct role in both technical reading abilities. Pitch discrimination had unique explanatory power only in reading fluency, while temporal discrimination was not distinguished as an explaining factor on its own. The results indicate that there is a connection between certain musical aptitude subskills and reading-related skills. However, because the Seashore test was created in a context of white Western music and due to other possible cultural biases in defining musicality, the results can only be generalised with caution.

Because of the correlational nature of the present study, no conclusions between the causality of the relationship between music and reading can be drawn. Firstly, replications of studies about link between musical aptitude and reading are needed to verify the link and to examine further how they are connected and whether pitch discrimination explains the connection. Secondly, longitudinal music intervention studies would be needed to determine whether a causal relationship exists. Yet, a severe lack of longitudinal studies with especially with a large number of participants persists – understandably due to practical reasons, such as lack of resources and high chance of attrition. Although meta-analyses attempt to account for differences between included studies, variability of chosen measures and possible biases in the studies will still impede drawing definite conclusions either for or against the benefits of musical aptitude or music training to reading skills.

The findings of this study, combined with previous literature, increase confidence about the existence of a relationship between musical aptitude and reading. Although uncertainties about the benefits of music training remain, I want to highlight that music education is valuable in itself because of the role of music in our culture. The cultural value of music is best observed in how socially rewarding musical interaction is. Simply listening to music or singing and dancing to it can connect people and enrich the bond between children and their parents. The joy in musical interaction also brightens school lessons and increases social and emotional wellbeing, which can further advance school motivation. Therefore, in case reading skills can be enhanced with music interventions in some children, such a benefit will only add to the value of music education.

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