Music Cognition and Linguistic Fluency

Investigating the cognitive influence of music education in relation to the development of language skills

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Abstract – English

The aim of the current pilot study was to investigate the relationship between music education and the development of language skills. The justification for this investigation was inspired by previous research, which reported a correlation between beat synchronization skills and oral reading fluency (Tierney & Kraus, 2013c). The present study expanded on these results by exploring whether beat synchronization skills also correlate with second language reading fluency. In addition, the current study was designed as an intervention in order to determine if music training with a focus on beat synchronization affects the development of language skills. Furthermore, heart rate data was recorded in the present study in order to investigate potential correlations between heart rate and tapping or reading performance, which may help to further explain the relationship between music and language abilities.

The results of the current study partially support the previous findings by Tierney and Kraus (2013c) that beat synchornization skills significantly correlate with reading fluency. The English reading performances evaluated in the current study were carried out by non-native English speakers, which provides evidence in support of the first hypothesis that beat syncrhhonzation skills also positively correlate with second langauge reading skills. Due to the low amount of statistically significant results, there was a lack of support for the second and third hypotheses that music training would affect language skills and that heart rate would correlate with tapping or reading performance. However, there were a number of trends observed in this pilot study which indicate the possibility that future studies with access to greater resources and refined methodological procedures may find an increased amount of statistically significant evidence supporting the notion that music training has the potential to benefit language development.

Abstrakt – Dansk

Formålet med dette pilotforsøg var at undersøge forholdet mellem musikundervisning og udviklingen af sproglige kompetencer. Begrundelsen for forsøget var inspireret af tidligere forskning, som har påvist en sammenhæng mellem kinæstetisk pulssynkronisering og færdigheder i flydende læsning (Tierney & Kraus, 2013c). Disse resultater er udvidet i dette pilotforsøg, som har udforsket sammenhængen mellem kinæstetisk pulssynkronisering og læsefærdigheder i engelsk som andetsprog. Forsøget var desuden konstrueret som en intervention, for at fastslå, om musikundervisning med fokus på kinæstetisk pulssynkronisering påvirker udviklingen af sprogfærdigheder. Endvidere blev data vedrørende hjertepuls samlet for at undersøge en potentiel sammenhæng med musik eller sprogfærdigheder, hvilket kunne bidrage til en yderligere forklaring af sammenhængen mellem musik og sprog.

Forsøgets resultater påviser en sammenhæng mellem kinæstetisk pulssynkronisering og flydende læsefærdigheder, og derved støtter de konklusionerne fra forsøget af Tierney og Kraus (2013c). Engelsklæsningerne i forsøget blev foretaget af forsøgspersoner som ikke havde engelsk som modersmål. Derfor tyder resultaterne også på, at der er en sammenhæng mellem kinæstetisk pulssynkronisering og læsefærdigheder i engelsk som andetsprog, som var forsøgets første hypotese. På grund af begrænsningen i mængden af statistisk signifikante resultater, kan resultaterne fra forsøget ikke støtte den anden og tredje hypotese, at musikundervisning ville påvirke sprogfærdigheder, og at hjertepulsen ville korrelere med synkronisering eller læsefærdigheder. Men der var en række tendenser i forsøget som antyder muligheden for, at fremtidige undersøgelser med adgang til flere ressourcer og mere raffinerede metodologiske procedurer, kan indhente en øget mængde statistisk signifikante resultater og dermed videre understøtte forestillingen om, at musikundervisning har potentialet til at udvikle sprogkompetencer.

1. INTRODUCTION

In the fifth century BC, Plato wrote, "I would teach children music, physics, and philosophy; but most importantly music, for the patterns in music and all the arts are the keys to learning" (Kelly, 2012, p. 152). The importance of the arts is still contemplated in contemporary society, especially during times of economic stress. Limited funding for school programs leads to debate surrounding which scholastic subjects should receive priority, and the arts are often neglected (Levitin, 2006). The significance of teaching the arts, however, is a notion that has been promoted since the fifth century BC.

Although it has long been suspected that arts play an important role in education, contemporary debate prefers to evaluate empirical evidence above suspicion. Many students who have received an arts education may agree with Plato's sentiments, but the precise effects of the arts on learning outcomes is difficult to prove tangibly. Nevertheless, an increasing amount of empirical research has been conducted in order to illuminate the benefits of arts training (Sparks, 2013). In particular, music is one field that has gained a lot of attention among scholars, largely due to the complex cognitive demands of music performance (Vuust, 2010).

Such research has revealed that music training correlates with numerous benefits, including enhanced linguistic skills, which is attributed to an overlap of cognitive mechanisms that process music and language. Recent studies have, for example, reported a correlation between kinesthetic synchronization abilities and oral reading fluency abilities (Slater, Tierney, & Kraus, 2013). Music training is one method of developing synchronized motor skills, however, it has yet to be determined if music training can also be attributed with improvements in linguistic fluency. There are indeed a number of factors that have the potential to influence the relationship between music and language. In order to further investigate this relationship, a pilot project was designed for the current study.

The specific aims of the current study, designed to expand on current research, included the investigation of 1) potential correlations between music and second language reading abilities, 2) potential effects of a music training intervention on reading fluency skills between a pre and post-test, and 3) potential physiological correlations with the execution of music and language tasks.

1.1. State-funded arts education

As state-funded school budgets are squeezed due to, for example, fluctuations in the global economy, various programs become forced to compete for limited funding in order to ensure their survival (Catterall, 2014). When solely regarded for aesthetic value, arts departments have notoriously become some of the first to suffer from budget cuts, as they are deemed less important than competing programs. Advocates are, however, adamant that the arts are vital for a holistic education as they enable students to develop skills that contribute to other areas of learning. Fine arts programs have, for example, been attributed with enhancing language, math, thinking, and social skills (Ruppert, 2006). Furthermore, arts programs are also often recognized for helping to elevate student motivation and positive learning environments by encouraging students to "think outside the box" (Gardiner, Fox, Knowles, & Jeffrey, 1996). These examples support the notion that the educational environment has the potential to flourish when propelled by creativity.

The importance of the arts, as a natural cultivator of creativity, has therefore been a topic of fierce debate in the face of state-funded school budget cuts. It has consequently become increasingly important to provide tangible evidence of how arts programs enhance educational curricula. However, it is difficult to objectively prove how students are affected by the arts, as there are a multitude of factors that can influence the outcome of a student's education including, but not limited to, social circumstances and inherent intelligence. Nevertheless, one study by Schellenberg (2015) aimed to reveal how student IQ levels changed after receiving arts training. One group of students received keyboard lessons, one group received voice lessons, one group received drama lessons, and a control group received no lessons. The results of this study indicated that the IQ levels of students who received music lessons increased more than students who received drama lessons or no lessons (Schellenberg, 2015). While general arts programs are beneficial in having the potential to foster educational creativity, such research indicates that music training offers particular benefits that are worthy of considerable attention in light of budget cuts.

1.2. Music education benefits

The unique benefits of music education have long been suspected, as documented in the writings of philosophers such as Aristotle and Plato over 2,000 years ago. The difficulties of proving such benefits, however, have been highlighted in contemporary research and subsequent critique. One study published in 1993 reported that spatial IQ scores were temporarily improved after listening to Mozart's sonata for two pianos in D major, K488 (Rauscher, Shaw, & Ky, 1993). These results were misinterpreted and led to claims that listening to music by Mozart made people smarter, a symptom aptly dubbed "The Mozart Effect." The study was highly scrutinized, and further research discredited the original findings (Larkin, 2004). The resulting controversy surrounding this study has led to skepticism towards further claims that engagement with music can lead to a transfer of any extracurricular benefits (Bonde, 2009).

There is indeed much we have yet to discover about the precise effects of music on learning and cognition. It is certainly difficult to tease apart the multitude of factors that consistently influence students in their learning environments. However, there are trends, which indicate that students who receive music training tend to fare better in a variety of areas compared to students who do not receive music training. For example, students who receive music training have been observed to become more successful in society, school, developing intelligence, and life altogether (Petress, 2005). It is, of course, conceivable that students who fare better in these areas are drawn to music, and that they innately possess a greater potential for success before their encounters with music. However, there is also evidence that students become more broadly successful as a result of their involvement in a music program, as parents have observed improvements in, for example, student behavior after joining a music program (Chorus America, 2009).

The perceived correlation between student success and involvement in music programs has provided enough evidence to continue researching whether or not music education is responsible for offering any benefits that extend beyond aesthetics. While the emotional and social benefits of music training are widely observed and worthy of recognition (Horn, 2013), the perceived cognitive benefits draw particular attention to scholastically relevant skills, which educational policy makers may prioritize for funding school programs. Although a complex field of study, research surrounding music and cognition has provided opportunity for uncovering pathways between diverse areas of information processing in the brain (Collins, 2014). Music performance has, in fact, been attributed with simultaneously igniting multiple sensory and cognitive domains including auditory perception, kinesthetic control, visual perception, pattern recognition, and memory (Barrett, Ashley, Strait, & Kraus, 2013). This provides evidence for explaining why music training has been reported to enhance cortical plasticity and cognitive function. The complex cognitive demands of music performance provide opportunity for investigating the changes in the brain that occur before and after music training. Such changes may affect areas of the brain that are not specific to music performance, which provides reason for supposing that developments in music skills can enhance other skills that share a cognitive overlap (Kraus, 2013).

Some cognitive areas of particular interest include the midline and lateral frontal areas, spatial processing areas, the temporal lobe, the frontal lobe, the cerebellum, and the corpus callosum (Cole, 2011). The midline and lateral frontal areas are of interest because they contain executive attention networks, which have been reported to be strengthened by music training, thereby enhancing concentration skills (Posner, Rothbart, Sheese, & Kieras, 2008). Spatial processing is another area that has been reported to be affected by music training, which correlates with improved geometry skills (Spelke, 2008). Music training is also reported to impact the temporal lobe, the frontal lobe, and the cerebellum, correlating with improvements in motor and auditory skills (Winner & Schlaug, 2009).

The implications of improved auditory skills are manifold. For example, musically trained individuals demonstrate a superior ability to perceive speech in noisy environments, as well as a superior ability to discriminate pitch, which enables individuals to better interpret meaning among speakers (i.e. if an utterance is a question or statement) and detect emotional qualities in speech (Kraus & Chandrasekaran, 2010). Furthermore, the size of the corpus callosum, which connects the left and right hemispheres of the brain, has been reported to increase as a result of music training, which corresponds with an improvement in language and reading skills (Wandell, Dougherty, Michal, Deutsch, & Tsang, 2008). Indeed, the correlation between music and language development is significant and may be a result of the anatomical overlap in the brain systems that process music and speech (Kraus, 2013).

1.3. Music and language

In 1871, Darwin postulated that the origin of our species' communicative abilities consisted of a form that was intermediate between modern language and music (Darwin, 1871). Contemporary archeologists and musicologists agree with this notion, and argue that music and language have evolved simultaneously, beginning with rhythmic grunts that were probably used to communicate before the existence of a concrete language (Huron, 2001; Mithen, 2006). Evidence for such theories may be detected in the existence of prosody in modern language. Prosody refers to the intonation, intensity, and stress of language, which can be respectively compared to the musical terms pitch, dynamic, and rhythm (Levitin, 2006). These musical aspects serve a crucial communicative component in modern language, as they indicate a speaker's emotion, the type of utterance (such as statement or question), as well as other linguistic elements that are not encoded by grammar or vocabulary such as irony, sarcasm, emphasis, etc. The musical elements that communicate this information in modern language may be a byproduct of evolutionary origins, providing evidence for theories that music and language evolved simultaneously.

Regardless of their origins, it is clear that music and language share points of intersection. Rhythm in language is one area in particular that has long attracted the attention of scholars. In 1945, Pike proposed a theory that different languages have different rhythms, which derive from varied patterns that are categorized as being stress-timed or syllable-timed (Pike, 1945). It is still accepted that each language has a unique rhythm, however, stress and syllable categories have been discredited because empirical research has demonstrated that the rhythmic differences in languages are not related to isochrony, or the division of time in equal portions (Patel, 2008).

This raises an important point that, although music and language share similarities, they are organized in different ways. While rhythm in music is organized by systematic units of measurement, rhythm in speech is instead "largely the by-product of phonological phenomena, such as the structure of syllables, vowel reduction, the location of lexical prominence, stress clash avoidance, and the prosodic phrasing of sentences" (Patel, 2008, p. 150). It is therefore unproductive to attempt to identify periodic rhythmic patterns in everyday speech, as such periodicity is only found in music. Recognizing this difference does not mean that meaningful comparisons between music and speech rhythm cannot be sought. On the contrary, by "abandoning a fixation on periodicity one is freed to think more broadly about speech rhythm and its relationship to musical rhythm" (Patel, 2008, p. 159). This contemporary theory has helped to further illuminate the reciprocal relationship between music and speech. For example, it has been discovered that it is not only possible to detect musical rhythms in speech, it is also possible to detect the unique speech rhythms of a composer's native language in music (Patel, Iversen, & Rosenberg, 2006).

Such findings further support the notion that music and language share basic processing mechanisms and that comparative studies of music and language are beneficial for exploring these mechanisms (Patel, 2008). Thus far, comparative studies have identified phonological awareness, speech-in-noise perception, rhythm perception, auditory working memory, and sound pattern learning as some of the processing mechanisms that connect music and language (Tierney & Kraus, 2013b). These neural functions are vital for reading and are purportedly enhanced by music training. For example, it is known that people who have reading disorders such as dyslexia are also found to exhibit timing difficulties in the domains of music and motor control (Overy, 2003). It can therefore be supposed that superior timing skills would correlate with both improved musical and reading abilities. Tierney and Kraus (2013a) confirmed this in studies that have investigated the relationship between reading ability and synchronized tapping. One such study in particular involved synchronization with the beat of a metronome by tapping, and it was reported that, among 58 participants, those whose tapping abilities were less variable also scored higher on reading performance tests (Tierney & Kraus, 2013c).

Tapping may be a seemingly simple task, but it is in fact a complex cognitive process which "places stringent demands on auditory processing, as listeners must accurately track the rhythm of the beat in order to reproduce it" (Tierney & Kraus, 2013c, p. 225). The primary beat synchronization tasks involved in Tierney and Kraus' (2013c) study therefore constituted tapping together with a beat, but their concurrent reference to rhythm raises an important distinction that calls for clarification. While rhythm refers to the "regulated succession of strong and weak elements" (Anon, 1971, p. 2537), beat refers to a series of short-duration stimuli that repeat at regular intervals and distinguish points in time (Winold, 1975). In other words, beat may be defined as the *consistent* pulse, or "heart beat," underlying a given piece of music, whereas rhythm is the *variation* of timing between notes. Rhythms may recur frequently, and beat may speed up or slow down with tempo changes. However, generally speaking, rhythm and beat may be respectively dichotomized by variation versus consistency. It is interesting that, although much of the linguistic research discussed thus far has focused on rhythms of language and music, the study by Tierney and Kraus (2013c) indicates that beat is the crucial connecting element between reading and tapping performance. This may be a result of the fact that, although beat and rhythm may be differentiated, they are codependent in the sense that accurate rhythms cannot be executed without a stable connection to the underlying beat.

1.4. Further research

Tierney and Kraus' (2013c) results inspire justification for a variety of further research to continue investigating the relationship between language and music. For example, since each language has a unique rhythm, it is worth considering whether beat synchronization abilities have the same correlation with reading abilities among individuals who have a native language other than English. In addition, if consistent tapping abilities correlate with improved reading skills, then it is possible that music training with a focus on beat synchronization skills could influence reading skills. Furthermore, because music tempo produces an arousal effect, with faster tempi causing faster heart rates, heart rate may be a worthy indicator of physiological correlations that could help to further explain the relationship between tapping and reading tasks (Bernardi, Porta, & Sleight, 2006). These avenues of enquiry were deemed best explored by means of a pilot study, in order to test methodological procedures that can be used and refined in future studies.

The present study, which aims to further illuminate the relationship between language and music,[1] was designed to expand on the research by Tierney and Kraus (2013c) by investigating 1) if tapping and reading abilities correlate among English as a second language (ESL) speakers, 2) if tapping and reading abilities improve after a music training intervention, and 3) if tapping and reading abilities mutually correlate with heart rate. It was hypothesized 1) that tapping and ESL reading abilities would correlate in both the pre and post-test, 2) that tapping and ESL reading abilities would improve in the post-test after receiving music training focused on the development of beat synchronization skills, and 3) that tapping and reading abilities would mutually correlate with heart rate.

[1] The specific components investigated in the current pilot study primarily revolve around beat synchronization and reading skills. However, the broad disciplines of music and language (that encompass beat synchronization and reading skills, respectively) are also frequently referred to in order to retain a wider perspective of the implications related to the study results.

2. METHODS

In order to replicate results by Tierney and Kraus (2013c), which show a correlation between synchronized tapping and reading performance, the current study initially proposed utilizing the same tapping and reading tests that were applied in the study by Tierney and Kraus (2013c). However, Tierney and Kraus (2013c) developed the tapping test in-house, and it is unfortunately not ready to be shared (personal communication, December 30, 2014). In addition, the reading tests (Test of Word Reading Efficiency and subtests of the Woodcock-Johnson Tests of Achievement) were inaccessible because the cost exceeded the means of this study. It was therefore necessary to devise alternate tests that were similar those used by Tierney and Kraus (2013c).

2.1. Participants

In order to maximize potential for tapping and reading improvement, participants for this study were recruited on the basis that they lacked formal music training and spoke English as a second language (the latter criteria was based on the assumption that second language reading skills are potentially inferior to first language reading skills). Previous studies have conducted music cognition research with children, whose developing brains possess heightened potential for learning (Skoe & Kraus, 2012). The current study might have also used younger participants in order to increase potential for improvement. However, it was deemed worth investigating if adults also are susceptible to cognitive influence of music training. A total of 16 adult participants with a mean (± standard deviation) age of 27.4 ± 8.9 years old, were therefore recruited for the current study, and 8 of them were male. The majority of participants (13) were university students, who responded to emails and flyers that were dispersed among various departments at Aalborg University. The remaining participants (three) were recruited via various social networks, including an English class at FOF Aalborg.

Participants were evenly divided into a control group and a training group. This was organized randomly, based on the amount of time a participant was prepared to offer; the time requirements of the control group were less demanding than the training group. The last participants to inquire were offered a spot in whichever group had the least number of participants, in order to ensure that the training and control groups were the same size. All participants offered their time on a volunteer basis; the only compensation they received was light refreshment upon attendance. Furthermore, all participants signed a consent release form, which outlined their role in the study, assured confidentiality of personal details, and confirmed their agreement to take part voluntarily (see Appendix A).

All of the participants in this study were neurologically healthy and did not have any disorders impairing their reading, movement, or listening skills. None of the participants declared English as a native language. The native languages in the training group included Danish (five participants), Spanish, Hungarian, Italian, and the native languages in the control group included Danish (six participants), French, and Slovakian. However, all of the participants were proficient enough in English to complete the required activities in this study. None of the participants declared an extensive history of music training. The highest levels of music training in the training group included six months or less of guitar training, C level high school music classes,[2] or primary school choir. The highest levels of music training in the control group included high school choir, C level high school music classes, or one year of youth piano training. All of this information was collected from a questionnaire prior to commencement of the study (see Section 2.2), and the results are compiled in Table 3.1.

2.2. Questionnaire

As previously noted, there are a multitude of factors that have the potential to affect a student's learning outcomes. Although Tierney and Kraus (2013c) reported a correlation between synchronized tapping and reading performance, these skills are not assumed to be exclusively interdependent, and they may be influenced by external variables. For example, it is conceivable that a participant with an extensive dance background may demonstrate more advanced tapping synchronization abilities, even though they lack formal music training. As a means of accounting for such variables, all participants in this study were asked to complete a questionnaire immediately prior to testing (see Appendix B).

There were a total of 23 questions, which were constructed in order to gain insight about factors that may influence tapping and reading abilities. Such factors included the following: number of languages spoken, highest level of education, occupation, utilization of English language skills, learning impairments, listening to music, dancing, physical activity,

[2] C level music classes are the lowest level of music classes offered at high schools (*gymnasium*) in Denmark.

and history of music training. Whenever appropriate, the Likert scale was employed, as a means of measuring perceived abilities and attitudes. This method asked participants to evaluate a question by giving a quantitative value on a graded scale where the extremes are polar opposites. For example, in order to measure perceived sense of rhythm, participants were given the following options to choose from: very poor, poor, average, good, or excellent. Some other questions asked about the frequency of participation in certain activities, such as speaking or writing in English, dancing, or sporting activities. For these questions, participants were presented with five temporal measurements including once per year or less, once per month, once per week, more than once per week, or daily. As ordinal measurements, the Likert scale and temporal frequency variables could be included in correlation analyses with the dependent variables from the tests to evaluate whether they had any influence on the results.

2.3. Test design

The tests compiled for this study in the absence of the original tests used by Tierney and Kraus (2013c) were selected based on their resemblance to the original tests as well as the time they required for completion. Especially considering that the participants in this study volunteered their time, 30 minutes was deemed an appropriate length of time for testing that would provide enough opportunity to collect a sufficient amount of data without exerting unreasonable demands on attention spans. Indeed, if the testing process was too long and tedious, it may have adversely affected participant concentration and their results.

In addition to tapping and reading performance tests, another test was included in this study, which evaluated beat perception. Although Tierney and Kraus (2013c) did not evaluate beat perception in their study, this was considered a relevant skill that had potential to supplement the data in the present study, especially since the original tests were not available. Including an analysis of beat perception skills also had potential to explain whether or not passive beat synchronization skills (listening, as opposed to active tapping) also correlate with reading skills. Furthermore, a beat perception test had already been designed by contemporary scholars and is available online, which rendered the test a credible inclusion in this study (Iversen & Patel, 2008). The pre and post-tests for the current study therefore comprised of three parts: tapping, beat perception, and reading.

The study took place over a four-week period, which was considered an appropriate length of time within the parameters of the academic semester. All participants in both the control and training groups were administered a 30-minute pre-test in the first week. The second and third weeks were reserved for training sessions. There were four sessions, and each session lasted one hour. All training group participants attended two sessions in the second week and two sessions in the third week, with at least one day in between each session in order to semi-equally disperse the amount of time between sessions. Finally, all participants in both the control and training groups were administered a post-test in the fourth week, which was identical to the pre-test with the exception of the reading (see Section 2.3.3).

2.3.1. Tapping

The tapping tests in the current study were executed using a computer software program (Audacity 2.1.0, open-source software, SourceForge.net) and an iPad application (Rhythm Pad, JSplash Apps, rhythmpad.com). Audacity is a multi-track audio editor that can play click tracks, or a series of beeps played at regular intervals, similar to a metronome. The speed of the click tracks could be adjusted to a pre-determined tempo and, while they were played, Audacity simultaneously recorded external sounds that were produced by tapping on the rhythm pad, which was placed 10 centimeters from the back of the computer screen so that the time for the sound to reach the computer microphone was consistent. The sounds recorded were displayed as a waveform in Audacity, and the sound of the Audacity metronome clicks produced a lower frequency waveform than the sound of tapping on the rhythm pad. Therefore, it was possible to measure distance between the sounds in milliseconds.

In order to model the in-house tapping test by Tierney and Kraus (2013c), each tapping trial in the present study consisted of 40 sound presentations, or metronome beeps, which were created by click tracks in Audacity. Participants were asked to tap on the rhythm pad together with the metronome as soon as they registered the sound. Data from the first 20 sound presentations were not analyzed in order to give participants ample time to synchronize with the metronome. There were two different tapping conditions, paced and unpaced, with a total of four trials for each condition. Two of the four trials in each condition were paced at 90 beats per minute (bpm) and the other two were paced at 120 bpm. These speeds were chosen because “they overlap with the rate of stressed syllable production in conversational speech” (Tierney & Kraus, 2013b, p. 14982). The order of the presentation of the speeds was randomized using a random number generator application, so as to avoid an order effect, which might have enabled participants to perform the second speed trial better having previously practiced the first.

The first set of four trials encompassed the paced tapping condition, which evaluated ability to tap a steady beat together with a metronome. The second set of four trials encompassed the unpaced tapping condition, which evaluated ability to tap a steady beat without the accompaniment of a metronome. The only difference in practical application between the two tapping conditions was the number of sound presentations generated by the Audacity click tracks. In the paced tapping condition, the metronome played all 40 sounds presentations and participants were instructed to tap together with the metronome until the clicks stopped. In the unpaced tapping condition, the metronome stopped after 20 sound presentations, but participants were instructed to continue tapping at the same rate without the metronome until 20 more taps had been collected, at which time they were verbally informed to stop tapping.

2.3.2. Beat perception

The beat perception portion of the test was introduced after completion of the tapping trials, and was acquired from the Beat Alignment Test (BAT) developed by Iversen and Patel (2008). The purpose of the BAT is to survey “beat processing abilities in the general population,” including musically untrained individuals (Iversen & Patel, 2008, p. 465). Additionally, the BAT is available for downloading online and is divided into three parts: synchronization with a metronome, synchronization with the beat of music, and perceptual judgment of the beat. Unfortunately, the first two parts require drum pad equipment that could not be funded for this pilot study; however, the third part did not require specialized equipment. This third part, which evaluated participants’ abilities to judge whether or not imposed beeps on a musical track were on or off the beat of the music, was therefore included in the present study.

There are a total of 24 musical excerpts included in the third part of the BAT, which incorporate three different genres of music: rock, jazz, and pop orchestral. If all of these examples were included, the total test time for the present study would have exceeded 30 minutes. Therefore, in order to economize testing time, six abridged subsets consisting of 18 musical excerpts from the full stimulus set were randomly selected. Although abridged, each subset still incorporated the three musical genres, which were each represented by two pieces. There were therefore a total of six different songs in each subset, and each song was played three times with varied beep timing: one with beeps that were too slow, one with beeps too fast, and one with beeps on the beat. Within these categories, the offbeat versions were either ahead or behind the beat by 10%, or they were ahead or behind by 30% of the inter-beat-interval, rendering the beeps out of phase with the actual beat (Iversen & Patel, 2008). The selection of off beats was randomized, but there was always one too fast and one too slow, in addition to the on beat version.

One of the six different subsets was randomly selected with a random number generator application for each participant. The order of the musical excerpts within each subset was also randomized using the same random number generator application for each participant. Before listening to any musical excerpts, participants were introduced to the beeps alone, so they could become familiar with the sound in order to differentiate the beeps from the music. Participants were then instructed to listen to the musical excerpts and determine, without tapping or moving, if the beeps were on or off the beat. Each musical excerpt lasted approximately 15 seconds, and the imposed beeps started after 5 seconds. At the end of each musical excerpt, participants were asked to answer if the beep was on or off the beat. They were also asked to rate their confidence of each answer by choosing from the following three categories: guessing, somewhat sure, or completely certain (given ordinal values of one, two, and three, respectively).

2.3.3. Reading

The reading tests employed by Tierney and Kraus (2013c) included subtests from the Test of Word Reading Efficiency (TOWRE) and subtests of the Woodcock-Johnson Tests of Achievement. The subtests selected from TOWRE included Sight Reading Efficiency (word reading) and Phonetic Decoding Efficiency (non-word reading). Both subtests evaluated reading fluency abilities, but the former applied actual words and the latter applied nonsense combinations of letters (Tierney & Kraus, 2013c). The subtests selected from the Woodcock-Johnson Tests of Achievement included Word Attack and Letter-Word ID. The Word Attack subtest assesses grapheme-to-phoneme translation, and the Letter-Word ID subtest assesses pronunciations associated with both familiar and unfamiliar word forms (Wendling, Schrank, & Schmitt, 2007). This information reveals that these tests primarily focus on oral reading fluency abilities.

Oral reading fluency refers to the oral translation of text with speed and accuracy, which is a salient characteristic of skillful reading (Adams, 1990). The ability to orally translate text is an important scholastic skill, because readers who demonstrate efficiency in "identifying anaphoric referents, integrating propositions within text, and […] inferencing," are consequently able to release additional attentional resources "for constructing a more in-depth text model," such as increased reading comprehension (Fuchs, Fuchs, Hosp, & Jenkins, 2001, p. 246). Oral reading fluency can therefore be an important indicator of overall reading competencies.

Because oral reading fluency is an important scholastic skill, there are numerous methods of assessing reading fluency skills. It is undeniably challenging to objectively assess such skills, because there are infinite nuances that affect speech patterns. However, Reading A-Z is an online company that provides resources for assessing oral reading skills, and their assessment guidelines resemble the assessment of cognitive processes in the TOWRE and Woodcock-Johnson subtests. The Reading A-Z tests did not encompass the application of nonsense combinations of letters, but there were some unusual names (such as "Beryl") that would presumably test instantaneity of unfamiliar grapheme-to-phoneme translation skills as in the TOWRE and Woodcock-Johnson subtests. The Reading A-Z reading fluency test guidelines were therefore considered appropriate an appropriate substitute for the TOWRE and Woodcock-Johnson subtests in the present study.

Although the reading assessment guidelines were generally appropriate, the selection of texts from Reading A-Z was not ideal because the highest level is designed for 9-11 year old students with English as their native language. However, even though the mean age of participants in the present study was 27.4 ± 8.9 years, none of them were native English speakers. The use of readings designated for a lower age level was therefore considered suitable for this pilot study to provide an approximate measurement of reading skills.

Two readings were required for the present study so that participants did not read the exact same text in the pre and post-tests. However, it was necessary for the readings to be the same level of difficulty and length. The highest level of reading difficultly, designed for 9-11 year olds in the Reading A-Z database, was categorized as level Z. Two readings in the level Z category both had exactly 299 words, so these readings were chosen for the present study because of their similar level of difficulty and length (see Appendix C). There was, however, a possibility that participants may have regarded one reading as more difficult than the other. Therefore, one reading was assigned to half of the participants and the other reading was assigned to the other half of the participants for the pre-test. The assignment of readings was randomized using a random number generator. In the post-test, participants were assigned whichever text they did not read in the pre-test.

The Reading A-Z fluency assessment guidelines produced two scores. The first score was the number of words read per minute, which was compared to the 160 words-per-minute target rate prescribed by Reading A-Z for 9-11 year old readers. The second score was an accuracy percentage, which was calculated based on the number of errors. Following the Reading A-Z guidelines, errors included: skipped words, mispronounced words, word substitutions (including incorrect forms of the word), words in the wrong order (both or all words are counted as wrong) and struggling that lasts for three or more seconds (Reading A-Z, 2015b). The Reading A-Z guidelines did not consider the following occurrences as errors: added words, varying pronunciation (due to accent, dialect, or speech impediment), repetitions in which the wording is correct, or self-correcting a mistake (Reading A-Z, 2015b).

These guidelines were initially used to score the reading performances in the current study. However, it became evident that there were many instances of repetitions and self-corrections, which interrupted the flow of reading performance. In researching the relationship between abilities to tap a steady beat and reading performance, it was determined that a steady flow was important for demonstrating fluent reading skills. Therefore, the assessment guidelines for this study adapted the guidelines by Reading A-Z, and included all of the following occurrences as errors: skipped words, mispronounced words, word substitutions (including incorrect forms of the word), words in the wrong order (both or all words are counted as wrong), struggling or hesitation which lasted for three or more seconds, added words, repetitions in which the wording is correct, and self-correcting a mistake. Varying pronunciations due to accent, dialect, or speech impediment were not considered errors, unless the word was unintelligible, in which case it was marked as mispronounced.

Participants were given a clean copy of only the text to read from (without extraneous information as on the marking copies listed in Appendix C), and each reading performance in both the pre and post-tests was recorded, so that they could be thoroughly assessed after the test. Following the guidelines outlined above, the author marked errors on a copy of the reading with a slash. The total number of errors was added up and then subtracted from the total number of words in the reading. This number was then divided by the total number of words in the reading, and multiplied by 100 to obtain a percentage that reflected reading accuracy.

Immediately after completing the reading in the pre and post-tests, the text was set aside and participants were asked to answer a series of true or false questions related to the content of the reading (see Appendix D). Previous studies have discovered a strong correlation between reading fluency and reading comprehension, because poor reading fluency "taxes the reader's capacity to construct an ongoing interpretation of the text" (Hudson, Lane, & Pullen, 2005, p. 703). It was therefore considered relevant to assess how much of the text was comprehended after a participant completed the reading. Comprehension questions were not included with the Reading A-Z resources, but each of the readings consisted of five paragraphs, which made it possible to construct one distinct question per paragraph. Each question was structured as a statement that was either copied directly from the text, or altered slightly, in which case the deviation from the original content reading was designed to be sufficiently noticeable so that participants had a fair chance of determining whether or not the content was correct. For each of the five questions, participants had the option of answering whether the statement was true or false. Participants were also given the option to concede that they could not remember, which was confidentially counted as a wrong answer. There is of course a 50% chance of providing a correct answer for a true or false statement even if participants are unsure, but having the third option of declaring uncertainty helped to increase the accuracy of comprehension scores since participants were not required to guess.

2.3.4. Heart rate

In order to investigate potential physiological correlations between tapping and reading performance, heart rate was measured throughout the duration of the pre and post-tests. Ideally, heart rate would have been measured continuously and recorded with computer software; however, such equipment was unfortunately unavailable for this pilot study. Therefore, a fitness heart rate monitor (F1, Polar, Finland) was used instead, which provided a means of approximating heart rate fluctuations throughout the test. Participants were given instructions regarding proper attachment of the heart rate monitor, and they were provided a moistened towelette to dampen the electrodes directly prior to affixation on the skin. Proper application of the heart rate monitor was confirmed when the heart rate monitor displayed an initial heart rate reading. Adjustments were sometimes required, but the testing did not commence until the heart rate monitor was properly affixed and measurements were displayed on the monitor.

Since the fitness heart rate monitor only displayed readings on a wrist watch that were not automatically recorded, there were several predetermined points during the test that were selected for manually recording heart rate readings (see Appendix E). Two baseline heart rate measurements were recorded while participants sat quietly and completed the questionnaire in the pre-test. The first measurement was recorded when participants were halfway through completing the first page of the questionnaire, and the second measurement was recorded when participants were halfway through completing the second page of the questionnaire. Two baseline heart rate measurements were also recorded prior to the post-test but, having completed the questionnaire, this took place over a period of two of minutes while participants sat quietly as final testing paperwork was organized.

Subsequent heart rate recordings were the same in both the pre and post-tests. During the tapping potions of the tests, one heart rate measurement was recorded approximately halfway through each tapping trial, of which there were eight. Three heart rate measurements were recorded during the beat perception portion of the tests, one after the sixth trial, one after the twelfth trial, and one after the eighteenth trial. Three heart rate measurements were also recorded during the reading portion of the tests, one when participants started reading, one after one minute of reading, and one at the end of the reading. The final heart rate measurement was recorded after participants had answered the last reading comprehension question.

There were a total of 17 heart rate measurements recorded per participant during each test. Occasionally, the heart rate measurement display changed while being recorded, in which case both numbers were recorded and the average of the two numbers was entered into the heart rate data spreadsheet. Although heart rate was not continuously recorded, this method of recording provided enough data to identify any trends in heart rate fluctuations throughout the tests.

2.4. Training

As an intervention project, the careful construction of a training program in between pre and post-tests was crucial for this study. The focus of the music training sessions emphasized beat synchronization skills in order to increase potential for improvements in tapping and reading performance in the post-test. The design of the training sessions was based on established educational approaches in order to promote and maximize the potential learning outcomes for training group participants. These educational theories were both general and specific to music education.

2.4.1. Education theories

General educational theory stipulates that learning is most productive when the curriculum is tailored to awaken potential among students (Booth, 2009). The task of tapping together with a metronome was employed in the testing phase of the current study as a means of testing beat synchronization abilities, however, it is a rather mundane activity that may have left participants feeling bored and uninspired if it had been the only skill practiced in the training sessions. Indeed, "a lack of variety in learning methods" can frustrate students and adversely impact their learning outcomes (Millbower, 2000, p. 46).

The importance of variety in an educational setting may be highlighted by the theory that humans possess at least seven different types of intelligence, including kinesthetic, interpersonal, intrapersonal, linguistic, logical, visual, and musical (Gardner, 1993). Strengths in each of these categories vary widely from person to person, rendering the incorporation a variety of learning methods important as a means of appealing to various strengths and therefore keeping students actively engaged in the learning process. Furthermore, the incorporation and development of a variety of intelligence categories is indeed considered important for facilitating a holistic education (Millbower, 2000). The methods and activities developed for enhancing beat synchronization abilities in this study were largely based on musical and kinesthetic intelligence, since these were the categories rendered most important for development based on participant background and lack of music training. Nevertheless, other types of intelligence were incorporated whenever possible in order to appeal to varied learning methods.

Not only were the training tasks varied in order to promote interest in learning, but each was also designed so that participants were given maximal opportunity to engage actively with the material. There is an educational philosophy known as learning by doing, which promotes the idea that the best way to acquire a new skill is to do it (Dewey, 1939). Furthermore, in 450 BC Confucius is reputed to have said, “Tell me and I will forget. Show me and I may remember. Involve me and I will understand” (Sørensen, 2006, p. 4). The concept of active participation as an effective educational tool is longstanding, and therefore inspired the design of the training sessions in this study.

The educational theories specific to music that inspired the design of training sessions in the current study include Dalcroze Eurhythmics, Suzuki, and Orff. Dalcroze Eurhythmics is a music education method developed in the 20th century by a Swiss musician and educator named Émile Jaques-Dalcroze. This method asserts that kinesthetic movement activities are particularly effective tools for cultivating musical expression among music students (Bachmann, 1991). Of particular interest to this study was the concept that such movement activities have the potential to instill a greater sense of rhythm. Although Dalcroze does not have a set curriculum, there are many activities promoted by contemporary music educators that are motivated by the Dalcroze philosophy (Abramson, 1997). Such activities were sought out for use in the training program of this study, some of which were used directly and others were adapted to inspire new types of exercises.

The Suzuki method is another field of music education that inspired the development of the training program in this study. Developed in the mid 20th century by Japanese violinist and educator Shin'ichi Suzuki, the Suzuki method is modeled on theories of natural acquisition, which stipulates that music, like language, is learned through exposure (Mora, 2000, p. 147). Expanding on this concept, Suzuki argued that, because a child learns to speak before they read, then music should be learned by ear before musical notation. This concept raised an important consideration for the current study, which was whether or not to include music theory as a part of the training sessions. Musical notation is of course a relevant aspect of learning to play music, and future studies with time for extensive training sessions may benefit from the inclusion of some music theory. However, it is not necessary to read musical notation in order to develop beat synchronization skills.

Therefore, music theory was not included as a part of the training sessions in this concentrated study, a decision justified by Suzuki's theory emphasizing the importance of learning to play music before learning to read music.

The third field of music education that inspired the development of training for this study was the Orff approach. This approach was developed in the 1920's by Carl Orff, a German composer who believed that natural behaviors such as singing, speaking, dancing, and playing were the most productive mediums of teaching music (Shamrock, 1986). This theory is reminiscent of Suzuki because it likens learning music with learning another natural system such as language, and it is reminiscent of Dalcroze because it promotes such learning through movement of playing. The combination of these areas, learning music through natural mediums that include behavioral movement, renders the Orff approach a unique and relevant parameter for the current study.

Five overarching areas of music movement were identified among Dalcroze, Suzuki, and Orff approaches that are strongly related to beat synchronization skills and were therefore rendered most relevant for the training program of the current study. These areas included drumming, dancing, singing, conducting, and piano skills, all of which were used to establish a framework for each training session (see Appendix F). The activities developed for each of these areas were repeated in each session to afford participants the opportunity to improve their skills that were required by each activity.

The music between each session was, however, different and slightly more complex in each successive session to encourage advancement of participant skills. Each session's corresponding piece of music provided musical accompaniment for all of the activities, which offered continuity in a lesson plan which otherwise consisted of disparate beat synchronization activities. The music was chosen from Volume 1 of the Suzuki Method piano books, all of which were folksongs with a simple structure that was accessible for musical novices (see Appendix G). The use of the same piece throughout each training session gave participants the opportunity to become very familiar with the melody. According to the Suzuki theory of ear training, this increased familiarity would enhance participant ability to play the song on the piano at the end of the session (Suzuki, 1995).

While the Dalcroze, Suzuki, and Orff approaches to music training are widely acclaimed, many of their beginning training activities are often utilized among children's groups as part of their first music lessons. These lower levels were necessary for the musically untrained adults who formed the participant panel for the current study; however, it was important that participants did not feel belittled by the activities they were asked to engage in. In order to maximize learning potential, it is important to ensure that the learning environment is sufficiently challenging but not overwhelming (Brewer & Campbell, 1991). Fortunately, the Volume 1 Suzuki folksongs that were selected for the current study are not archetypical children's songs. There are other children's songs that would have been an appropriate technical level to include with this study, but were avoided because of their associated connotations. One of the Suzuki pieces chosen for one of the training sessions was titled *French Children's Song*; however, the title was not shared with participants and none of the participants indicated that they recognized the piece, let alone the potentially juvenile association. The Suzuki pieces utilized were selected based on their appropriate level of complexity and lack of widespread association with a juvenile learning environment in order to sufficiently challenge them and meet educational expectations.

Participants attended each of the four training sessions together with one training partner. Training partnerships were organized based on schedule and availability, and each participant had the same training partner for all four sessions. The organization of training partners for this study was based on evidence that social partners reciprocate motivation for synchronizing body movements to an external beat (Kirschner & Tomasello, 2009). Furthermore, it has been observed that when people interact they "either move together (in whole or in part) or they don't and in failing to do so are disruptive to others around them" (Hall, 1976, p. 71). It was therefore considered beneficial to assign training partners as a means of encouraging gravitation toward synchronous movements. In addition, there were several training activities designed for this study that required a partner. Having a consistent training partner during all four sessions was also a deliberate means of fostering interpersonal intelligence and therefore a positive learning environment. However, there were no more than two participants per session, in order to ensure that they were afforded a maximal level of personal attention and guidance from the instructor, which may have been compromised in larger groups.

The levels of accomplishment between training groups was naturally varied, and some participants required extra training in particular areas over others. Extra time was spent on basic areas of beat synchronization if necessary in order to allow participants the opportunity to fully grasp the basic concepts before moving on to the more complex aspect of piano training. However, even when more time was spent on basic training, the timing was adjusted accordingly so that some time was afforded for each activity, ensuring that all participants had at least some level of exposure to all of the beat synchronization activities, including piano.

2.4.2. Practical application

To summarize the practical application of the training sessions, as justified in the sections above, there were four one-hour training sessions, which took place over a two-week period. There was at least one day in between each session in order to semi-equally disperse the amount of time between sessions. The sessions consisted of beat synchronization activities developed from a framework incorporating drumming, dancing, singing, conducting, and piano skills. Each of the activities in these areas was accompanied by a corresponding folksong. These activities were rehearsed in all of the training sessions in order to establish basic skills, and the different folksong in each session incorporated slight technical advancements in order to facilitate the development of skills (see Section 2.4.7). Participants were assigned a consistent training partner, and the time spent on each activity was adjusted according to participant level, however, time was appropriately managed so that all participants received at least some exposure to all activities.

2.4.3. Drumming

Each training session started with activities related to the first area of beat synchronization framework designed for the current study, which was drumming. This term is used broadly for the purpose of this study and denotes producing synchronized sounds with devices controlled by upper limbs. The drumming tool used in the first activity was a simple chopstick. Participants were asked to listen to a folksong that was played on the piano and, when they had identified the beat, they were asked to tap the beat on the piano case. This exercise could have also been executed by tapping with a finger, but the chopstick functioned as an amplifier of the sound of tapping without damaging the piano case. This activity served to introduce the basic concept of beat synchronization at the beginning of each lesson.

In the second activity, participants were asked to tap the rhythm of the melody in the folksong, at which time the concept of rhythm was explained in contrast to beat. If participants demonstrated an ability to discriminate between beat and rhythm, they were challenged in the third activity to tap the beat of the music in their non-dominant hand while simultaneously tapping the rhythm of the melody in their dominant hand. Many of the participants had difficulty with this activity, but having distinguished between beat and rhythm, it was a good introduction to the next exercises, which combined elements of drumming and dancing.

2.4.4. Dancing

As with drumming, the term dancing is also broadly used for the purpose of this study, denoting beat synchronization produced by movement of the feet. Dancing may be considered an independent discipline, but for the purpose of this study, music and dance were considered highly interdisciplinary. The inclusion of dance facilitated variety in the training activities, and variety has previously been identified as an important component of a productive learning environment (Millbower, 2000). Furthermore, dance is a commonly utilized medium in Dalcroze training for cultivating musical expression. It was therefore considered highly relevant to include a dance component in the design of the current beat training program.

Thus, in the fourth activity, participants were asked to walk in place together with the beat, with one footstep per beat. Having established the feeling of the beat in their feet, they were then asked to clap the rhythm of the melody with their hands while it was played on the piano. Building off of this exercise, participants were asked in the fifth activity to walk in place to the beat of the folksong while it was played on the piano. Participants were instructed to stop walking and start clapping the beat whenever the music stopped randomly. When the music started again, they were instructed to stop clapping and start walking to the beat again. This exercise trained steady beat synchronization abilities both with and without accompaniment, which would be tested in the paced and unpaced tapping tests.

The next activities expanded on drumming and dancing skills by including a bouncing ball, which is a training tool commonly used in Dalcroze exercises. The sixth activity therefore involved bouncing a ball to the beat of the music, and it was emphasized that not only did the ball have to bounce on the beat but it also had to be caught on the subsequent beat. The seventh activity expanded on this concept, and the training partners were instructed to alternate bouncing, where the first participant bounced their ball on beats one and three and the second participant bounced their ball on beats two and four. Having established this higher level of coordination, they were then instructed in the eighth activity to bounce one ball between each other, still emphasizing the timing of both bouncing and catching with the beat.

After participants demonstrated a sufficient ability and comfort level with the bouncing tasks, they were they asked to learn a simple dance choreography in the ninth activity that incorporated bouncing a ball. The incorporation of bouncing was intended to keep participants sufficiently challenged and take the focus off the act of dancing, which has potential to cause insecurity. The dance steps were simple, and they were rehearsed several times with and without accompaniment until the participants could perform the steps for the duration of the folksong to the beat and without instruction. All of the dancing activities were accompanied by the folksong played on the piano in order to guide beat synchronization.

2.4.5. Singing

Singing is also an activity that requires kinesthetic beat synchronization and is therefore a useful training tool. However, there were several participants who expressed anxiety about singing, which threatened a comfortable learning environment. Singing as a training activity was therefore not consistently exercised during the training sessions, as participants were not required to engage in an activity that made them uncomfortable. In some instances, participants were slightly more receptive toward the concept of singing, in which case they were encouraged to hum the melody of the folksong while simultaneously executing the bouncing activities. If they were comfortable with humming, then they were also encouraged to sing the melody on “do.” The combination of singing with another activity was intended to take the focus off the act of singing and therefore reduce potential anxiety. It is possible that, with additional training sessions, more participants would have become comfortable with singing. However, perhaps due to the lack of training sessions, only some of the participants reached a level of comfort with singing, which enabled them to combine singing with the bouncing activities.

2.4.6. Conducting

There were no distinct activities designated for singing, due to circumstances surrounding insecurity. The next activity therefore shifted the focus to conducting skills, which require a high level of synchronization abilities. Participants were initially introduced to conducting patterns that reflected the appropriate time signature of the session's corresponding folksong. The folksongs assigned for the first and third sessions were in common time, and the folksongs assigned for the second and fourth sessions were in ¾ time. This gave participants the opportunity to become acquainted with two of the most common time signatures, and they were challenged to learn how the time signatures differed as a means of advancing their knowledge of how beat is organized in music.

The even time signatures in the folksongs chosen for training sessions were most appropriately conducted in two because of their corresponding tempos. This was therefore the first conducting pattern introduced in the first session, where each measure began with a downward movement and finished with an upward movement. The conducting pattern for ¾ time was introduced in the second session and required a slightly more advanced pattern, starting down on one, then right on two, and up on three. In both patterns, participants were instructed to emphasize the first beat by submitting to the forces of gravity on beat one in order to clearly mark the start beat of each measure. Both conducting patterns were also drawn on a blackboard to appeal to participants' visual intelligence, which they may have responded better to than kinesthetic movements.

Participants were given the opportunity to warm up for the conducting activities by first practicing the appropriate conducting patterns with their dominant hand. Once they demonstrated the ability to execute the pattern correctly, they were asked in the tenth activity to synchronize their conducting pattern with their training partner by using a small piece of rope. There was a knot tied on either end of the rope, which was placed between the index and middle fingers on the palm side of the hand of each participant. They were then instructed to keep the rope taut, so that it was not limp, but neither pulled too hard. The use of the rope in this exercise promoted beat synchronization between training partners as they conducted the accompaniment of the folksong on the piano.

In the eleventh activity, participants were asked to make sure that the beats of their conducting corresponded with the beats of the folksong being played on the piano. The tempo was sporadically sped up and slowed down on the piano to ensure that the participants demonstrated movements that corresponded to the actual beat as opposed to making the prescribed movements at regular intervals. Having been afforded the opportunity to become reasonably comfortable with the conducting patterns by executing the above activities, participants were then asked to control the tempo themselves by conducting the pianist, whose playing reflected the participants' conducted tempo.

2.4.7. Piano

The twelfth and final activity for each training session involved learning to play the respective folksong on the piano. This activity was saved for the end of the training session not only because it was the most complex beat synchronization activity, but also because toward the end of the session participants had been exposed to the sound of each melody repeatedly from its use as accompaniment for the preceding activities. This type of preparation equipped participants with a natural approach of learning to play the song by ear, according to Suzuki (International Suzuki Association, 2015). This is one of the reasons that the pieces were chosen from the Suzuki Volume 1 piano book, in addition to the reasons that they comprise an appropriate level of complexity and lack of connotation as a children's song.

Each of the pieces chosen consisted of 16 measures with a five-note melodic figure, where one of each of the notes corresponded with one finger on the right hand, without the need to change fingering positions. They were therefore considered basic enough for musical novices to learn to play, however, each piece contained slightly more advanced elements than the previous in order to promote advancement in learning. The piece chosen for the first training session, *Lightly Row*, was in an even time signature (cut-time), and the notes in each measure were divided evenly, without dotted note values. The piece for the second training session, *Cuckoo*, introduced the ¾ time signature which is slightly more difficult to conduct, but still had evenly divided note values. The piece for the third training session, *French Children's Song*, was another example of an evenly valued time signature (common time), however, it introduced dotted note values. The last piece, *Goodbye to Winter*, was another example of a ¾ time signature, but it also included dotted note values and faster rhythms; in addition to whole, half, and quarter notes, there were also eighth notes. During the training activities, the instructor played the pieces with left hand accompaniment. When participants were given the opportunity to learn to play the piece, they were instructed on how to play with melody of the piece with their right hand only.

Piano training was executed using one piano where the instructor sat in the middle of the two participants. Participants were first instructed on how to position their fingers on the keys, which, for the first three pieces, revolved around placement of the thumb on the C key, and in the last piece revolved around placement of the thumb on G. Once the correct fingering was in place, the first few measures of the piece was demonstrated on the same piano and participants were asked to repeat the performance on the same piano in a different octave. This method of instruction continued until the hour long session was nearly finished. Some participants mastered basic skills so efficiently that they had 20 minutes to learn to play the folksong on the piano, whereas other participants required more time on basic skills and may have only had five minutes available for piano training, in which case they were only instructed on how to play the first couple of measures of the piece.

Participants who were afforded more time for piano playing due to their efficient accomplishment of basic synchronization skills were generally able to learn to play all 16 measures of the piece. If confident enough, training partners were then assigned their own piano to play on for the remainder of the session. In addition, if participants were successful playing the right hand of the melody on their own, the instructor provided left-hand accompaniment to harmonize with the melody.

Towards the end of the session, a metronome was introduced and participants were instructed to play as much of the piece as they could in time with the metronome. While playing without a metronome reinforced unpaced beat synchronization abilities, playing with a metronome reinforced their paced beat synchronization abilities. The speed of the metronome started slower and was gradually increased with each successful attempt as appropriate. The speeds ranged between 90 and 120 bpm, to match the approximate speeds of the tapping trials. The session ended with a final performance, which comprised however much of the piece the participants were able to play. Repeating the portion of the piece that participants could successfully complete at the end of the session served to reinforce the positive learning environment and retain motivation for future learning.

2.5. Data analysis

To analyze the data recorded in the two tapping tasks (paced and unpaced), Audacity was used to mark and record the onset times of the last 20 (out of 40) taps for each trial (two paced and two unpaced) for each tapping frequency (90 or 120 bpm) for each test (pre and post) among each participant. The actual (paced) or expected (unpaced) metronome beat onset times were also calculated for the last 20 taps for each individual trial in Audacity. These values were entered into an excel spreadsheet where the calculations for the dependent variables were made.

Three dependent variables (outcome measures) were extracted from these data for each individual trial. The first was the *absolute mean difference (in seconds) between the actual (or expected) onset of the metronome beat and the participant's recorded tap* (see Equation 1). In order to obtain an overall representative score of tapping accuracy, the absolute value was calculated to determine how far (in seconds) the tapping occurred from the metronome, regardless of whether the participant was early or late. The absolute value therefore removed any bias of being too slow or too fast. A lower absolute mean difference indicated that the participants were better at matching the actual or expected metronome beat time. For each testing session, the absolute mean difference was calculated separately for the two paced and two unpaced trials at each tapping frequency. The mean of these two trials was calculated for each participant at both of the different frequencies for both paced and unpaced tapping.

$$Absolute\ mean\ difference\ = \frac{|\sum metronome\ onset - tap\ onset|}{number\ of\ trials} \qquad (1)$$

The second dependent variable was the *absolute error in mean tapping frequency*. A lower absolute mean error in tapping frequency indicated that participants were better at matching the tapping frequency specified by the metronome (either 90 or 120 bpm). The absolute value was calculated in order to remove any bias of being too slow or too fast. The tapping frequency (in bpm) for each trial was calculated by first finding the mean difference (in seconds) between subsequent taps by the participant (in seconds). This value was then converted into a frequency (see Equation 2).

$$Tapping\ frequency = \frac{1}{mean\ diff.between\ subsequent\ taps} \cdot 60\ seconds \qquad (2)$$

The absolute difference between the actual tapping frequency for each trial and the required tapping frequency for that trial (either 90 or 120 bpm) was then calculated separately for the paced and unpaced tapping tasks (see Equation 3). The mean of the two different trials at each tapping frequency was calculated as the final *absolute error in mean tapping frequency* for each participant.

$$Abs. error\ in\ mean\ tap. freq. = \ |tapping\ freq. - req. tapping\ freq.| \qquad (3)$$

The final dependent variable for the tapping tasks was the *mean variability between subsequent taps*. A lower mean variability indicated that the participants' tapping performances were more consistent. This was calculated as the standard deviation of the difference (in seconds) between subsequent taps for each trial. The mean of the two standard deviations for each trial for each tapping frequency was calculated for both paced and unpaced tapping as the final *mean variability between subsequent taps*.

The dependent variables for the beat perception task were 1) percentage correct, 2) percentage correct and completely certain, 3) the mean confidence rating of correct answers, and 4) the mean confidence rating of incorrect answers. The dependent variables for the reading test were 1) reading speed (words per minute), 2) accuracy percentage, and 3) the percentage correct for the reading comprehension questions.

For the heart rate data, the mean heart rate at each different phase of testing was calculated for each participant. For example, two heart rates were recorded at baseline, so the mean of these two values was calculated. Heart rate was recorded during each of the tapping trials, so the mean heart rate over the two trials for each frequency for the paced and unpaced tapping was calculated. Furthermore, the mean values of the three heart rates recorded during the beat perception task were also calculated, since the presentation order of the music tracks was randomized. The heart rate measurements recorded during the reading tests were not averaged because there was only one corresponding recording (reading start, reading one minute, reading stop, reading comprehension). This resulted in a total of ten different values for heart rate.

2.6. Statistical analysis

All dependent variables for tapping performance, beat perception performance, reading performance, and heart rate were analyzed using separate two-way repeated measures analyses of variance (ANOVAs), with time (pre-test, post-test) as the within-subjects factor, and group (test, control) as the between subjects factor. Differences with a probability of < 0.05 were considered significant.

In order to extend on the research conducted by Tierney and Kraus (2013c) and test the hypotheses that tapping and ESL reading abilities would correlate in both the pre and post-tests, and to test the hypothesis that tapping and reading abilities would mutually correlate with heart rate, Pearson's correlation coefficients were calculated for the following combinations of dependent variables: 1) reading performance dependent variables were compared with each other; 2) reading performance dependent variables were compared with all tapping performance (paced and unpaced) and beat perception performance dependent variables; 3) reading performance, tapping performance, and beat perception performance dependent variables were compared with the corresponding heart rate recordings for each phase of testing and baseline heart rate. Correlation coefficients were calculated separately for the pre and post-tests, and due to the limited number of participants, data from both the training and control groups were included in each of the correlations.

Furthermore, in order to determine whether individual characteristics of the participants collected in the questionnaire had an influence on the experimental data, variables from the questionnaire concerning English (hours speaking English, and frequency of reading, listening to, and writing English) were correlated with the dependent variables from the pre-test for reading performance. Additionally, variables from the questionnaire concerning music and physical coordination (frequency listening to music, dancing, participating in sports, and ratings of sense of rhythm and physical coordination) were correlated with the dependent variables from the pre-test for tapping performance. Questionnaire correlations were only performed on data from the pre-test in order to provide insight regarding the initial ability of participants, which was the ultimate purpose of the questionnaire. Data from both the training and control groups were included in each of the correlations. Pearson's correlation coefficients were calculated for the combinations including hours speaking English, while all other correlations for the questionnaire data were Spearman's rho correlation coefficients because the remaining variables from the questionnaire were ordinal.

As previously noted, due to varied ability in executing the basic beat training activities, some participants in the training group were afforded more time at the end of the session for piano training. To investigate whether this had any influence on the dependent variables from the pre to post-tests, participants were ranked from one to eight in order of performance ability during training by the author, since participants with superior performance abilities efficiently mastered the basic beat synchronization activities and there were afforded more time for piano training at the end of the session. These rankings were correlated with the percent changes in all dependent variables from the pre to post-tests using Spearman's rho correlation coefficients. All Pearson's and Spearman's rho correlations with a probability of < 0.05 were considered significant.

3. RESULTS

Due to the relatively low number of participants in this pilot study, the ANOVAs for all tested dependent variables revealed no significant main or interaction effects of group or time (all p's > 0.05). Therefore, all results presented below will be based on trends of differences observed in the data. Unless otherwise specified, the results represent means ± standard deviations.

3.1. Questionnaire

The information collected from the questionnaire that all participants completed prior to the pre-test is summarized below in Table 3.1.

Table 3.1: Summary of participant information from the questionnaire for training and control groups. Unless otherwise specified, numbers represent number of participants. Standard deviations are in brackets.

	Training Group	Control Group
Number	8	8
Gender	5 male; 3 female	3 male; 5 female
Age (years)	29.5 (12.6)	25.3 (1.3)
Dominant Hand	7 right; 1 left	7 right; 1 left
Nationality	5 Danish; 1 Costa Rican; 1 Hungarian; 1 Italian	6 Danish; 1 French; 1 Slovakian
Native language	5 Danish; 1 Spanish; 1 Hungarian; 1 Italian	6 Danish; 1 French; 1 Slovakian
Other fluent languages	6 English; 1 Spanish	7 English; 1 German; 1 Danish; 1 Polish
Highest English exam	2 high school level A; 2 high school level B; 2 TOEFL; 1 IELTS; 1 real exam	6 high school level A; 1 high school level B; 1 high school level C
Occupation	7 university students; 1 electrician	6 university students; 1 physical therapist; 1 on sick leave
Hours speaking English per week	25.5 (33.3)	14.4 (18.2)
English speaking activities	4 work; 2 English class; 3 university lectures; 4 socializing	1 work; 4 socializing; 1 all day; 1 university lectures; 1 video games; 1 English class
Reading in English	4 daily; 3 more than once per week; 1 once per week	6 daily; 1 more than once per week; 1 once per year or less
Listening to English	4 daily; 2 more than once per week; 2 once per week	6 daily; 2 more than once per week
Writing in English	4 daily; 3 once per week; 1 once per year or less	3 daily; 3 more than once per week; 1 once per month; 1 once per year or less
Listening to music	7 daily; 1 once per week	5 daily; 2 more than once per week; 1 once per week
Dancing	1 more than once per week; 3 once per month; 4 once per year or less	2 more than once per week; 3 once per month; 3 once per year or less
Sense of rhythm	1 good; 3 average; 2 poor; 2 very poor	1 good; 3 average; 4 poor
Physical coordination	1 good; 3 average; 4 clumsy	1 good; 5 average; 2 clumsy
Sports	4 more than once per week; 1 once per week; 2 once per month; 1 once per year or less	1 daily; 3 more than once per week; 1 once per week; 2 once per month; 1 once per year or less
Sports activities	1 soccer; 2 swimming; 1 gym; 1 judo; 2 biking; 1 floorball; 1 running	1 running; 2 gym; 2 walking; 2 biking; 1 soccer
Music training	4 yes; 4 no	3 yes; 5 no
Kind of music training	1 high school level C; 2 < 6 months guitar; choir	2 choir; 1 piano lessons for 1 year
Still receiving music training	4 no	1 yes (choir once per week); 2 no
How long ago stopped	Between 6 months and 6 years ago	Between 10 and 15 years ago

3.2. Tapping performance

Three calculations were applied to the 90 and 120 bpm results from both the paced and unpaced tapping tests, which include absolute mean difference between expected metronome time and tapping, absolute error in mean tapping frequency, and mean variability between beats.

3.2.1. Paced tapping

The calculations for absolute mean difference between metronome and tapping times for the 90 bpm paced tapping trials revealed that the training group was more accurate in the pre-test, with a difference of 0.092 ± 0.059 seconds, than the control group with a difference of 0.129 ± 0.113 seconds. Both groups improved in the post-test, where the absolute mean difference of the training group was 0.059 ± 0.024 seconds, and the difference of the control group was 0.083 ± 0.065 seconds. The training group improved by 35.9% and the control group improved by 35.7% (see Figure 3.1A).

The calculations for absolute mean difference between metronome and tapping times for the 120 bpm paced tapping trials revealed that the training group was less accurate in the pre-test, with a difference of 0.156 ± 0.216 seconds, than the control group, with a difference of 0.113 ± 0.09 seconds. Both groups improved in the post-test, where the absolute mean difference of the training group was 0.056 ± 0.053 seconds, and the difference of the control group was 0.070 ± 0.044 seconds. The training group improved by 64.1% and the control group improved by 38.1% (see Figure 3.1B).

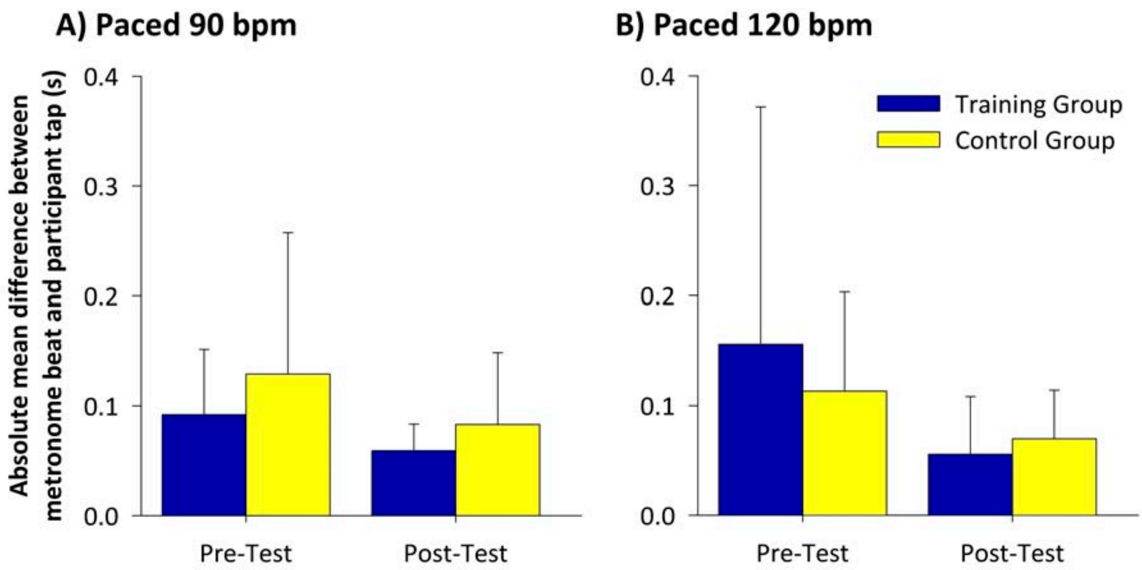

Figure 3.1: Absolute mean difference between metronome beat and participant tap (in seconds) for the training (blue bars) and control (yellow bars) groups from the paced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

The calculations for absolute error in mean tapping frequency for the 90 bpm paced tapping trials revealed that the training group was slightly more accurate the pre-test, with an error of 0.44 ± 0.56 bpm, than the control group, with an error of 0.76 ± 0.84 bpm. In the post-test, the training group became less accurate, with an error of 0.51 ± 0.61 bpm and the control group improved, with an error of 0.62 ± 0.67 bpm. The training group became less accurate by 15.9% whereas the control group improved by 18.4% (see Figure 3.2A).

The calculations for absolute error in mean tapping frequency for the 120 bpm paced tapping trials revealed that the training group was slightly more accurate in the pre-test, with an error of 2.17 ± 3.72 bpm, than the control group, with an error of 2.75 ± 3.85 bpm. Both groups improved in the post-test, where the absolute error of the training group was 1.44 ± 2.81 and the error of the control group was 1.02 ± 1.41 bpm. The training group improved by 33.6% and the control group improved by 62.9% (see Figure 3.2B).

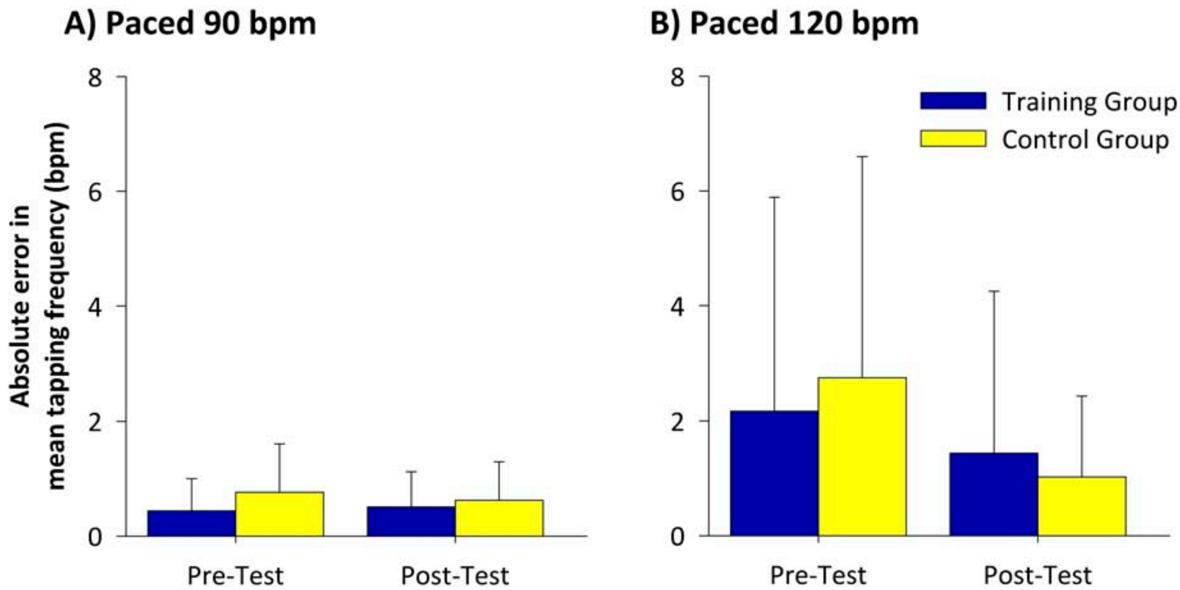

Figure 3.2: Absolute error in mean tapping frequency (in bpm) for the training (blue bars) and control (yellow bars) groups from the paced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

The calculations for mean variability between beats for the 90 bpm paced tapping trials revealed that the training group was less accurate in the pre-test, with a mean variability of 0.066 ± 0.047 seconds, than the control group, with a mean variability of 0.048 ± 0.014 seconds. Both groups improved in the post-test, where the mean variability of the training group was 0.032 ± 0.011 seconds and the mean variability of the control group was

0.043 ± 0.030 seconds. The training group improved by 52.9% and the control group improved by 10.4% (see Figure 3.3A).

The calculations for mean variability between beats for the 120 bpm paced tapping trials revealed that the training group was more accurate in the pre-test, with a mean variability of 0.031 ± 0.007 seconds, than the control group, with a mean variability of 0.041 ± 0.019 seconds. In the post-test, the training group improved, with a mean variability of 0.027 ± 0.009 seconds, and the control group became less accurate with a mean variability of 0.043 ± 0.030 seconds. The training group improved by 12.9% and the control group became less accurate by 4.9% (see Figure 3.3B).

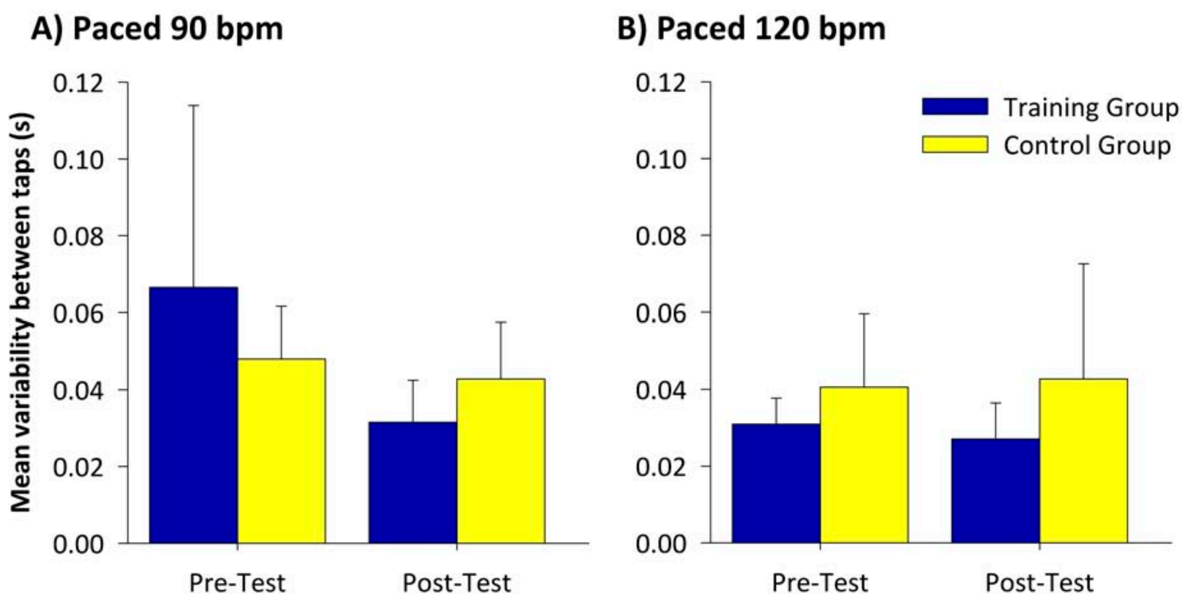

Figure 3.3: Mean variability between taps (in seconds) for the training (blue bars) and control (yellow bars) groups from the paced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

3.2.2. Unpaced tapping

The calculations for absolute mean difference between expected metronome and tapping times for the 90 bpm unpaced tapping trials revealed that the training group was less accurate in the pre-test, with a difference of 0.291 ± 0.333 seconds, than the control group, with a difference of 0.264 ± 0.048 seconds. Both groups improved in the post-test, where the absolute mean difference of the training group was 0.188 ± 0.139 seconds, and the difference of the control group was 0.242 ± 0.139 seconds. The training group improved by 35.4% and the control group improved by 0.5% (see Figure 3.4A).

The calculations for absolute mean difference between expected metronome and tapping times for the 120 bpm unpaced tapping trials revealed that the training group was more accurate in the pre-test, with a difference of 0.181 ± 0.111 seconds, than the control group, with a difference of 0.217 ± 0.098 seconds. Both groups improved in the post-test, where the absolute mean difference of the training group was 0.139 ± 0.106 seconds, and the difference of the control group was 0.145 ± 0.074 seconds. The training group improved by 23% and the control group improved by 33.2% (see Figure 3.4B).

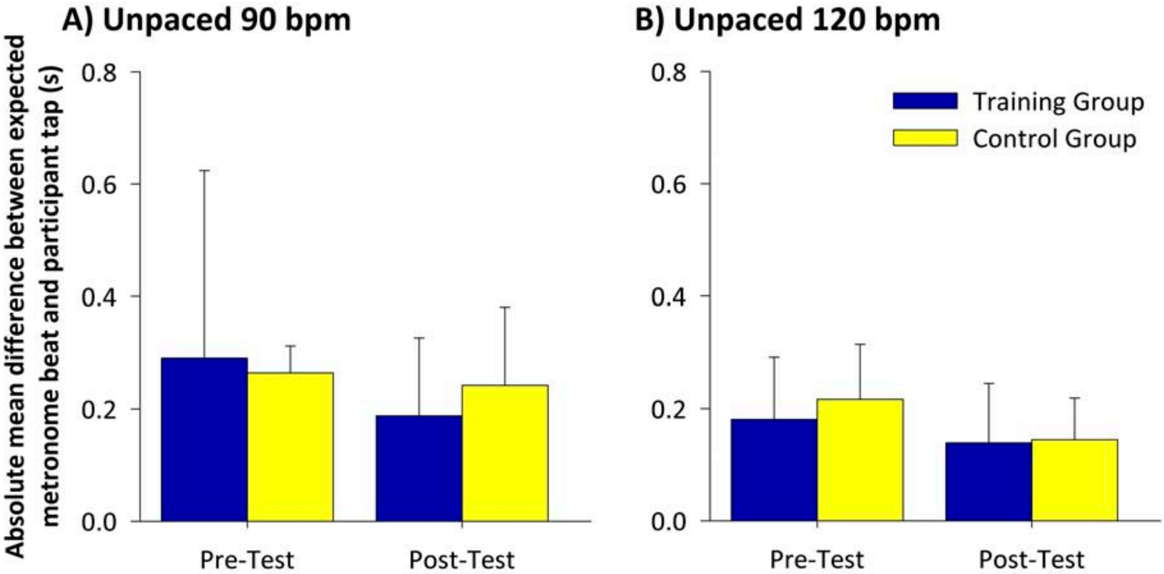

Figure 3.4: Absolute mean difference between expected metronome beat and participant tap (in seconds) for the training (blue bars) and control (yellow bars) groups from the unpaced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

The calculations for absolute error in mean tapping frequency for the 90 bpm unpaced tapping trials revealed that the training group was less accurate in the pre-test, with an error of 4.0 ± 5.17 bpm, than the control group, with an error of 2.63 ± 1.48 bpm. Both groups improved in the post-test, where the absolute error of the training group was 2.64 ± 2.42 bpm, and error of the control group was 2.62 ± 2.07 bpm. The training group improved by 34% and the control group improved by 0.4% (see Figure 3.5A).

The calculations for absolute error in mean tapping frequency for the 120 bpm unpaced tapping trials revealed that the training group was less accurate in the pre-test, with an error of 5.03 ± 5.28 bpm, than the control group, with an error of 3.19 ± 2.53 bpm. Both groups improved in the post-test, where the absolute error of the training group was 2.67 ± 2.19 and the error of the control group was 2.08 ± 1.67 bpm. The training group improved by 46.9%, and the control group improved by 34.9% (see Figure 3.5B).

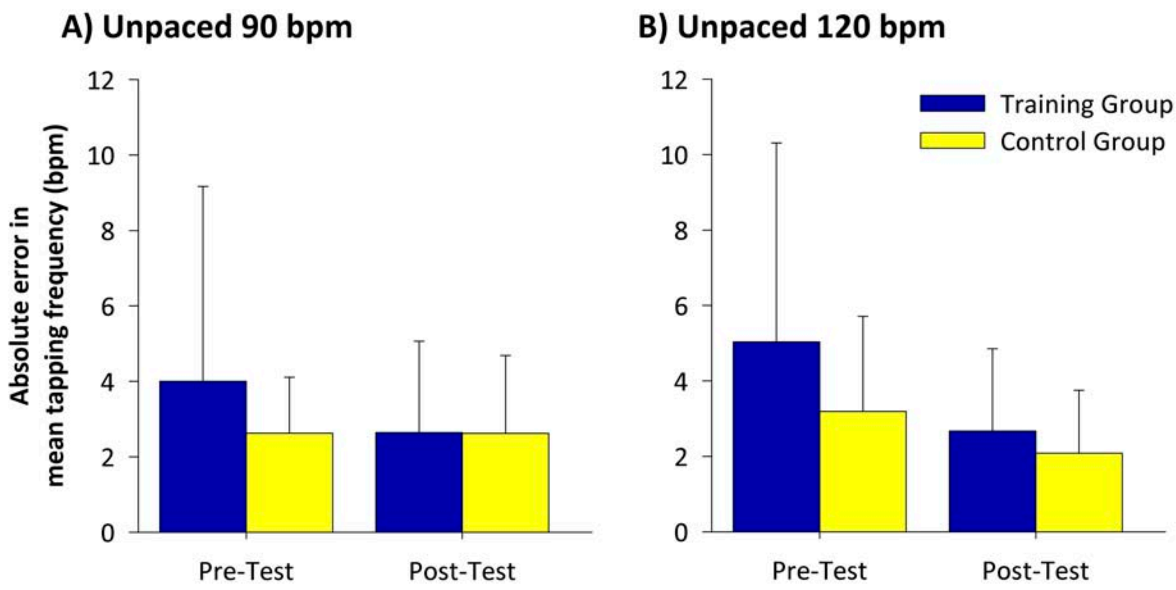

Figure 3.5: Absolute error in mean tapping frequency (in bpm) for the training (blue bars) and control (yellow bars) groups from the unpaced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

The calculations for mean variability between beats for the 90 bpm unpaced tapping trials revealed that the training group was more accurate in the pre-test, with a mean variability of 0.045 ± 0.029 seconds, than the control group, with a mean variability of 0.058 ± 0.039 seconds. Both groups became less accurate in the post-test, where the mean variability of the training group was 0.059 ± 0.076 seconds and the mean variability of the control group was 0.084 ± 0.059 seconds. The training group became less accurate by 1.4% and the control group became less accurate by 44.8% (see Figure 3.6A).

The calculations for mean variability between beats for the 120 bpm unpaced tapping trials revealed that the training group was less accurate in the pre-test, with a mean variability of 0.063 ± 0.092 seconds, than the control group, with a mean variability of 0.034 ± 0.013 seconds. In the post-test, the training group improved, with a mean variability of 0.027 ± 0.015 seconds, and the control group became less accurate with a mean variability of 0.039 ± 0.018 seconds. The training group improved by 57.1% and the control group became less accurate by 14.7% (see Figure 3.6B).

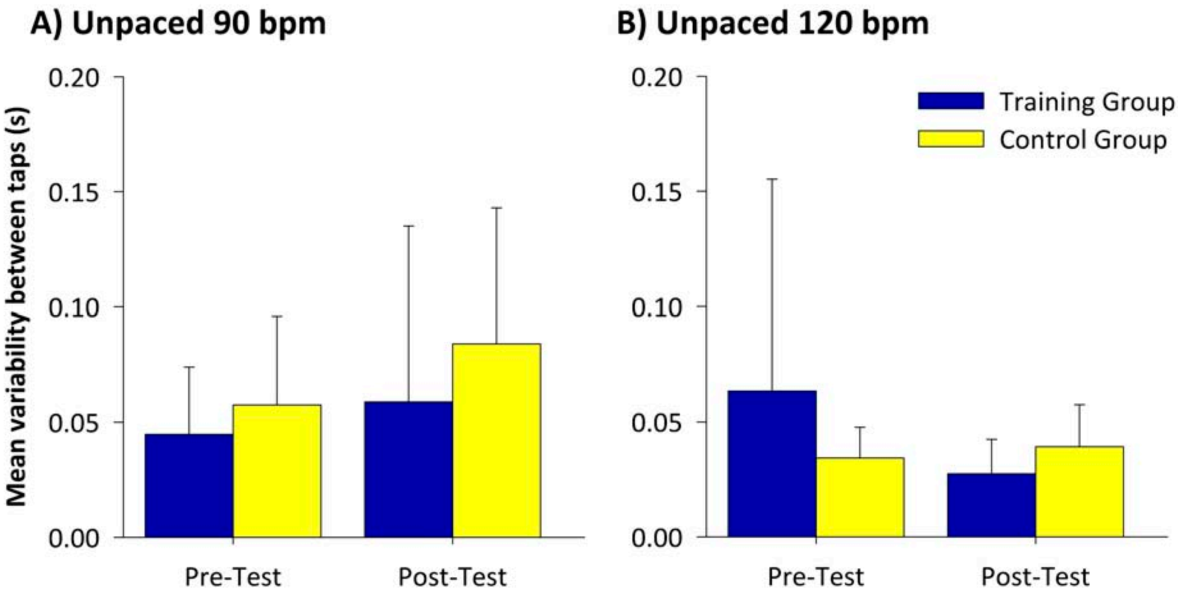

Figure 3.6: Mean variability between taps (in seconds) for the training (blue bars) and control (yellow bars) groups from the unpaced tapping task at 90 (A) and 120 (B) bpm in the pre and post-tests. Error bars represent standard deviations.

3.3. Beat perception performance

In the pre-test, the average percentage of correct answers for the 18 beat perception trials was 79.17 ± 17.76% in the training group and 73.61 ± 11.79% in the control group. In the post-test, the average percentage of correct answers for the 18 beat perception trials was 79.17 ± 18.25% in the training group and 72.22 ± 16.27% in the control group. The average percentage of correct answers did not change in the training group and decreased by 1.92% in the control group (see Figure 3.7A).

In the pre-test, the average percentage of correct answers that were also rated completely certain was 27.08 ± 23.65% in the training group and 24.31 ± 19.23% in the control group. In the post-test, the average percentage of correct answers that were also rated completely certain was 36.11 ± 30.28% in the training group and 22.22 ± 24.31% in the control group. The average percentage of correct answers increased by 25.01% in the training group and decreased by 9.41% in the control group (see Figure 3.7B).

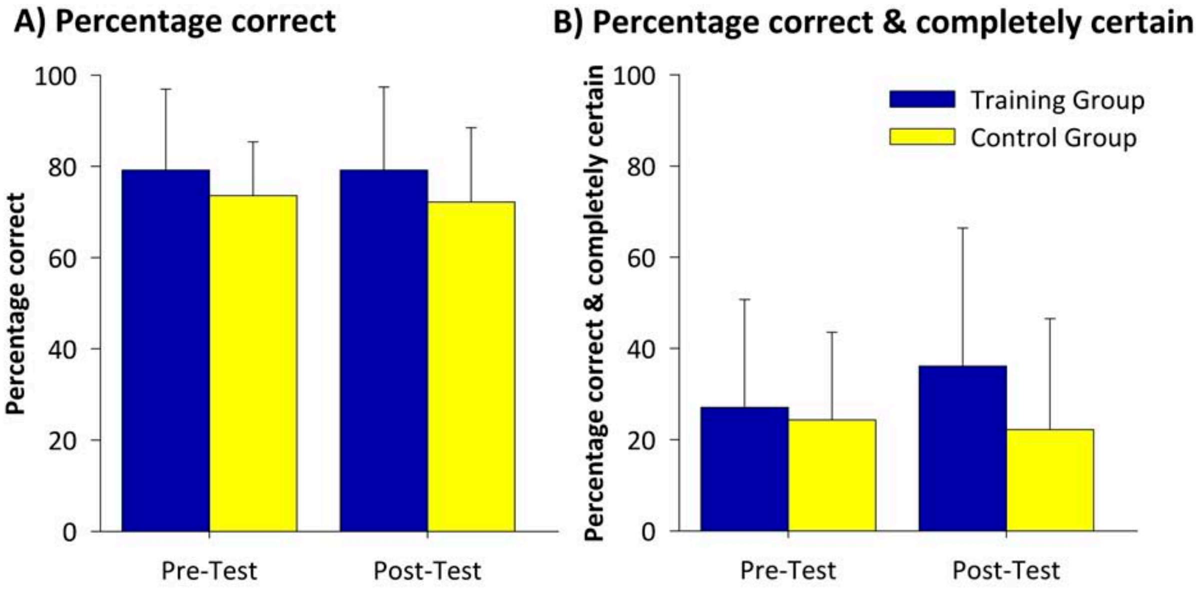

Figure 3.7: Percentage correct (A) and percentage correct with a completely certain confidence rating (B) for the training (blue bars) and control (yellow bars) groups from the beat perception task in the pre and post-tests. Error bars represent standard deviations.

In the pre-test, the mean confidence rating of correct answers was 2.15 ± 0.45 in the training group and 2.13 ± 0.37 in the control group. In the post-test, the mean confidence rating of correct answers was 2.29 ± 0.40 in the training group and 2.05 ± 0.49 in the control group. The mean confidence rating of correct answers increased by 6.11% in the training group and decreased by 3.90% in the control group (see Figure 3.8A).

In the pre-test, the mean confidence rating of incorrect answers was 1.79 ± 0.48 in the training group and 1.44 ± 0.40 in the control group. In the post-test, the mean confidence rating of incorrect answers was 1.69 ± 0.47 in the training group and 1.79 ± 0.54 in the control group. The mean confidence rating of incorrect answers decreased by 5.92% in the training group and increased by 19.55% in the control group (see Figure 3.8B).

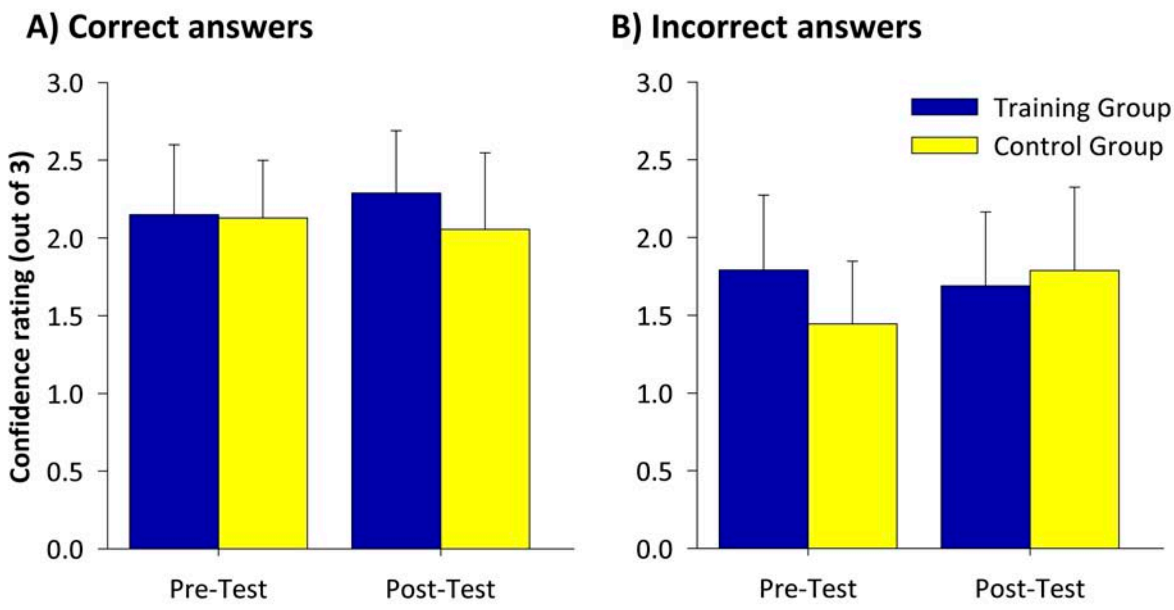

Figure 3.8: Mean confidence rating following correct (A) and incorrect (B) answers for the training (blue bars) and control (yellow bars) groups from the beat perception task in the pre and post-tests. Error bars represent standard deviations.

3.4. Reading performance

The mean score for reading accuracy in the pre-test was 94.23% ± 3.65 in the training group and 93.74 ± 4.22% in the control group. The mean score for reading accuracy in the post-test was 95.32 ± 2.62% in the training group and 92.60 ± 4.99% in the control group. The mean score for reading accuracy improved by 1.14% in the training group and decreased by 1.23% in the control group (see Figure 3.9A).

It is worth noting the differences between individual reading accuracy scores in the pre and post-tests. There were five training group participants who scored a higher reading accuracy percentage in the post-test than the pre-test (see Figure 3.9B) compared to only one control group participant (see Figure 3.9C).

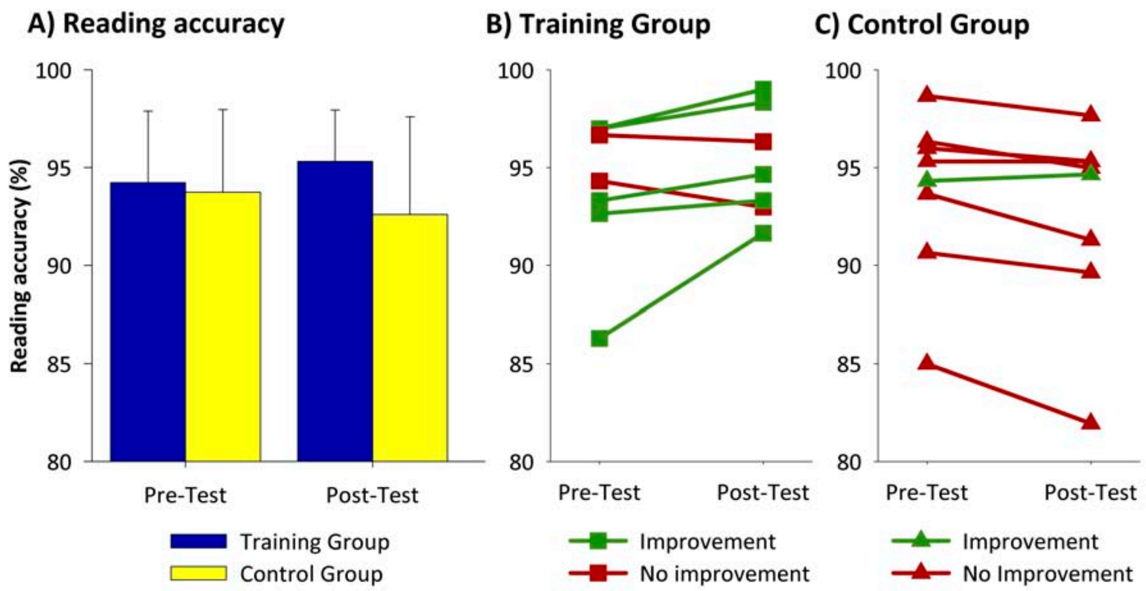

Figure 3.9: Mean reading accuracy percentage (A) for the training (blue bars) and control (yellow bars) groups from the reading task in the pre and post-tests. Error bars represent standard deviations. Panels B and C represent the individual reading accuracy percentages for the training and control groups, respectively. Green symbols and lines denote participants who improved their reading accuracy percentage from the pre to post-test, while the red symbols and lines denote participants who did not improve. Only seven participants are visible in the training group because two participants received the exact same scores (no improvement).

The mean reading speed in the pre-test was 152.63 ± 30.55 words per minute in the training group and 142 ± 31.84 words per minute in the control group. The mean reading speed in the post-test was 150.38 ± 28.08 words per minute in the training group and 146.88 ± 29.55 words per minute in the control group. The mean reading speed decreased by 1.50% in the training group and improved by 3.32% in the control group (see Figure 3.10A). The mean reading speeds for both groups were under the target reading speed for 9-11 year old native English speakers is 160 words/minute (Reading A-Z, 2015a), which is represented by the horizontal dashed line in Figure 3.10A.

The mean percentage of correct reading comprehension answers in the pre-test was 77.5 ± 27.12% for the training group and 57.5 ± 16.69% for the control group. In the post-test, the average percentage of correct answers was 75 ± 20.70% for the training group and 75 ± 20.70% for the control group. The mean percentage of correct reading comprehension answers decreased by 3.33% in the training group and increased by 23.33% in the control group (see Figure 3.10B).

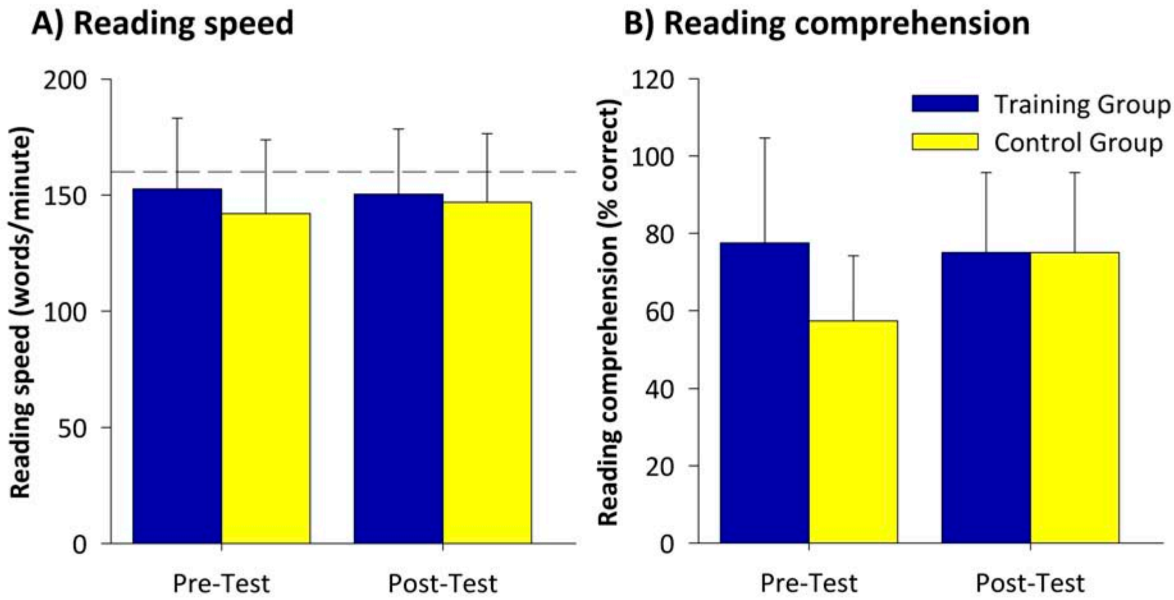

Figure 3.10: Mean reading speed (A) and mean reading comprehension scores (B) for the training (blue bars) and control (yellow bars) groups from the reading task in the pre and post-tests. Error bars represent standard deviations. The horizontal dashed line in panel A represents the target reading speed (160 words/minute) for 9-11 year old native English speakers as prescribed by Reading A-Z (2015a).

3.5. Heart rate

A summary of the mean heart rate data across all participants in the training and control groups during the ten different measurement times during the pre and post-tests, including means and standard deviations, are provided in Table 3.2 and Figure 3.11. Because there were no significant differences in the mean heart rate data, and because mean heart rate was not a primary dependent variable, further analyses of trends were not carried out. However, the heart rate data were included in correlation analyses (see Section 3.6).

Table 3.2: Summary of mean heart rate (beats/minute) for both training and control groups at each of the ten different measurement times during the pre and post-tests. Standard deviations are in brackets.

	Training Group		Control Group	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Baseline	71.5 (5.6)	74.1 (12.6)	85.0 (16.3)	86.6 (16.4)
Paced 90	75.9 (14.6)	73.6 (13.0)	81.1 (20.4)	87.6 (11.5)
Paced 120	88.6 (36.5)	76.8 (17.0)	84.2 (18.2)	89.6 (17.4)
Unpaced 90	82.6 (33.8)	72.3 (11.9)	83.3 (19.6)	86.2 (10.2)
Unpaced 120	82.4 (29.9)	71.4 (10.5)	84.1 (17.9)	98.7 (14.1)
Beat perception	75.4 (9.8)	71.5 (9.0)	83.0 (17.2)	84.0 (12.6)
Reading start	83.4 (10.4)	82.4 (12.5)	93.5 (18.7)	91.0 (17.7)
Reading 1 min	76.8 (7.7)	75.8 (12.8)	88.5 (19.8)	86.3 (17.4)
Reading stop	71.9 (8.3)	73.8 (14.4)	84.5 (16.2)	83.5 (14.4)
Reading comp.	70.1 (9.0)	71.3 (12.7)	85.9 (19.8)	83.5 (16.4)

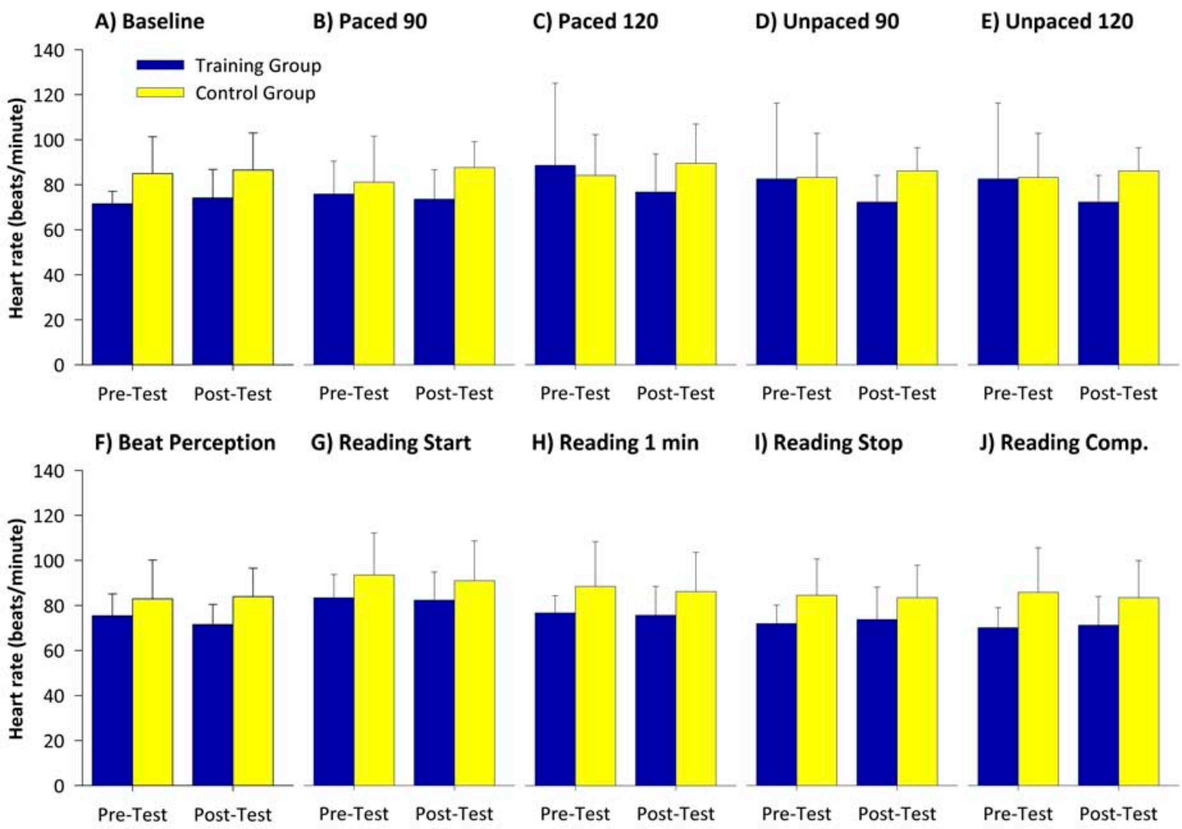

Figure 3.11: Mean heart rate for both training (blue bars) and control (yellow bars) groups at each of the ten different measurement times during the pre and post-tests. Error bars represent standard deviation.

3.6. Correlation analyses

3.6.1. Correlation of reading performance, tapping performance, beat perception performance, and heart rate variables

The results of the correlation analyses of reading performance dependent variables with tapping and beat perception performance dependent variables for both the pre and post-tests, including *p*-values for significant correlations, are presented in Appendix H Section 7.8.1. Furthermore, the results of the correlation analyses of reading performance, tapping performance, and beat perception performance dependent variables with the corresponding heart rate measurements for the pre and post-tests, including *p*-values for significant correlations, are presented in Appendix H Section 7.8.2. The significant correlations for the pre-test (performance variables only) and post-tests (performance variables and heart rate) are presented graphically in Figure 3.12, Figure 3.13, and Figure 3.14 respectively.

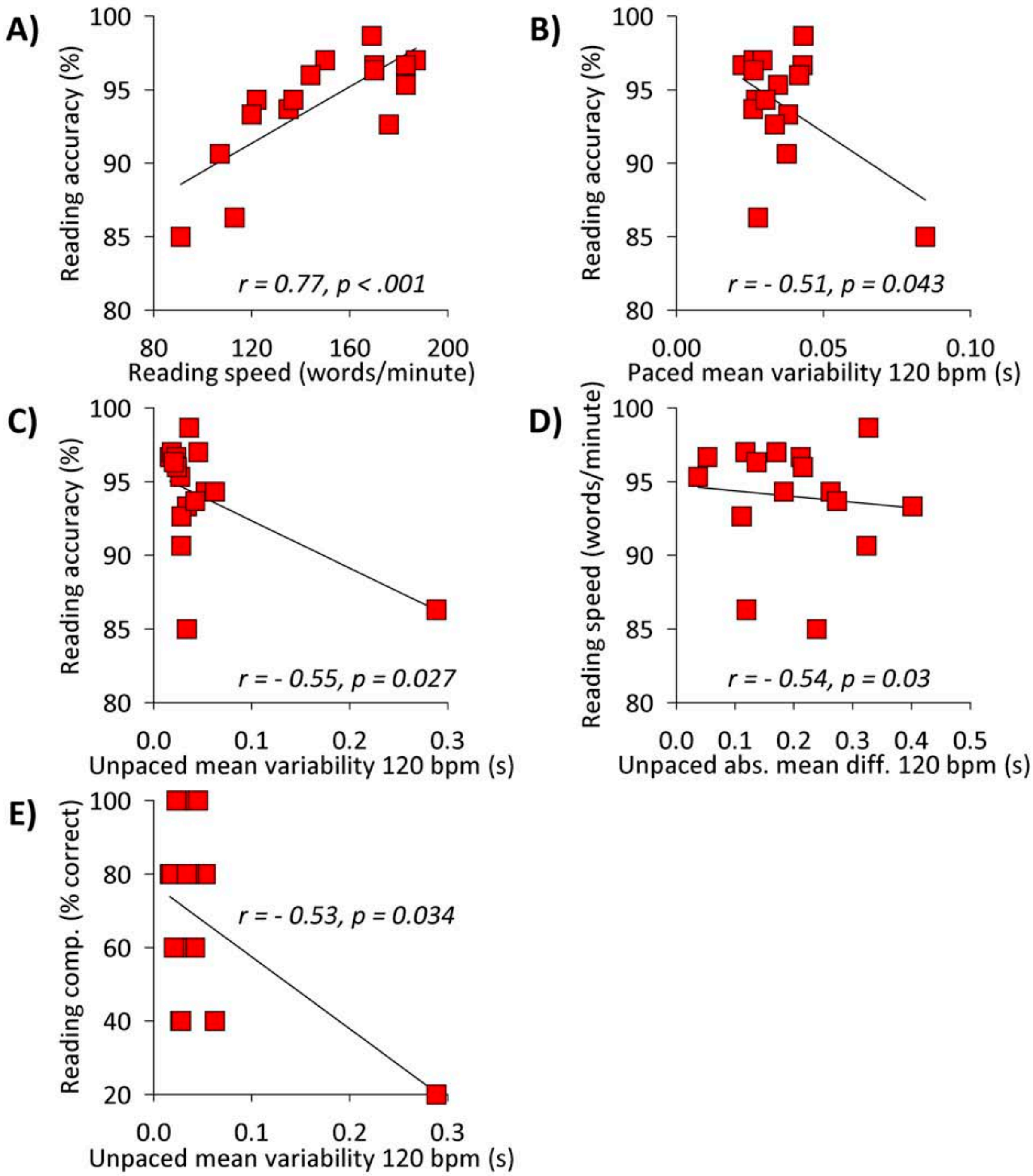

Figure 3.12: Scatter plots for significant correlations of reading performance dependent variables with tapping and beat perception performance dependent variables for the pre-test. Correlation coefficients and *p*-values are provided for each significant correlation.

In the pre-test, reading accuracy was positively correlated with reading speed (r = 0.772, $p < 0.001$), i.e. more accurate readers also read faster (Figure 3.12A). In addition, reading accuracy was negatively correlated with the mean tapping variability during the paced (r = -0.511, p = 0.043) and unpaced (r = -0.551, p = 0.027) tapping tasks at 120 bpm, i.e. more accurate readers were less variable at tapping during the paced and unpaced tapping tasks at 120 bpm (Figure 3.12B & C).

Furthermore, reading speed was negatively correlated with the absolute mean difference between the expected metronome time and participant actual tap time in unpaced tapping at 120 bpm (r = -0.542, p = 0.03), i.e. faster readers tapped closer to the expected metronome time in the unpaced tapping task at 120 bpm (Figure 3.12D). Finally, reading comprehension was negatively correlated with the mean tapping variability in the unpaced tapping task at 120 bpm (r = -0.532, p = 0.034), i.e. participants with better reading comprehension were less variable at tapping during the unpaced tapping task at 120 bpm (Figure 3.12E). There were no other significant correlations in the pre-test (see Appendix H Section 7.8.1).

In the pre-test, heart rate was not significantly correlated with any reading, tapping (paced and unpaced), or beat perception variables (all p's > 0.05; see Appendix H Section 7.8.2).

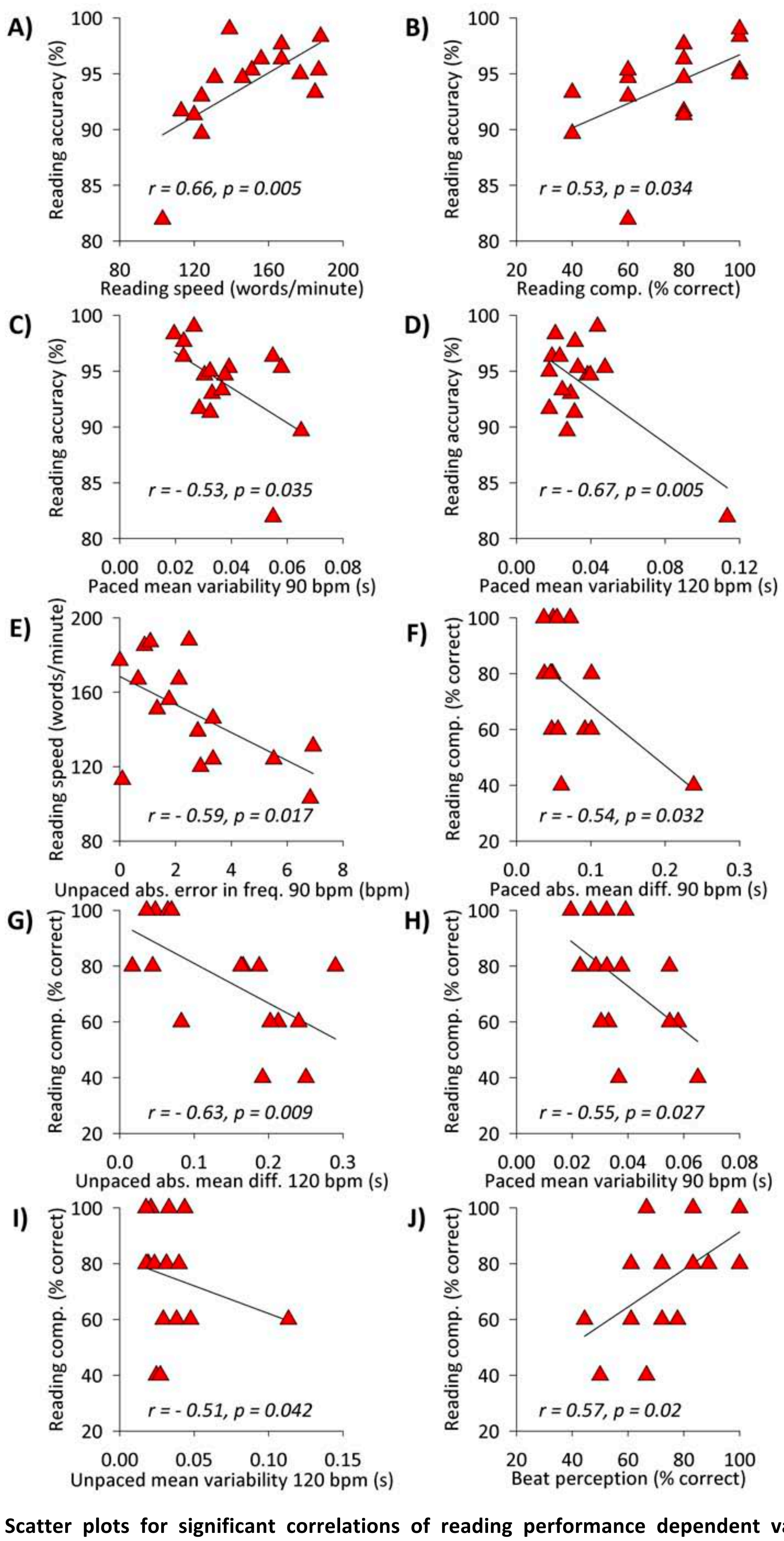

Figure 3.13: Scatter plots for significant correlations of reading performance dependent variables with tapping and beat perception performance dependent variables for the post-test. Correlation coefficients and *p*-values are provided for each significant correlation.

In the post-test, reading accuracy was also positively correlated with reading speed in the post-test (r = 0.663, p = 0.005), in addition to being positively correlated with reading comprehension (r = 0.532, p = 0.034), i.e. more accurate readers were both faster readers and more accurate in the reading comprehension test (Figure 3.13A & B).

Reading accuracy was negatively correlated with the mean tapping variability during the paced tapping task at 90 (r = -0.53, p = 0.035) and 120 bpm (r = -0.665, p = 0.005), i.e. more accurate readers were less variable at tapping during the paced tapping tasks at 90 and 120 bpm (Figure 3.13C & D). In addition, reading speed was negatively correlated with the absolute mean error in tapping frequency during the unpaced tapping task at 90 bpm (r = -0.585, p = 0.017), i.e. faster readers tapped closer to the specified tapping frequency during the unpaced tapping task at 90 bpm (Figure 3.13E).

Reading comprehension was negatively correlated with the absolute mean difference between the metronome time and participant actual tap time during the paced tapping task at 90 bpm (r = -0.536, p = 0.032), i.e. participants with better reading comprehension tapped closer to the metronome during the paced tapping task at 90 bpm (Figure 3.13F). Reading comprehension was also negatively correlated with the absolute mean difference between the expected metronome time and participant actual tap time during the unpaced tapping task at 120 bpm (r = -0.63, p = 0.009), i.e. participants with better reading comprehension tapped closer to the expected metronome time during the unpaced tapping task at 120 bpm (Figure 3.13G).

In addition, reading comprehension was negatively correlated with the mean tapping variability during the paced tapping task at 90 bpm (r = -0.55, p = 0.027) and the unpaced tapping task at 120 bpm (r = -0.514, p = 0.042), i.e. participants with better reading comprehension were less variable at tapping during the paced tapping task at 90 bpm and in the unpaced tapping task at 120 bpm (Figure 3.13H & I). Finally, reading comprehension was positively correlated with percentage of correct and completely certain answers during the beat perception task (r = 0.575, p = 0.02), i.e. participants with better reading comprehension were more often correct and completely certain during the beat perception task (Figure 3.13J). There were no other significant correlations in the post-test (all p's > 0.05; see Appendix H Section 7.8.1).

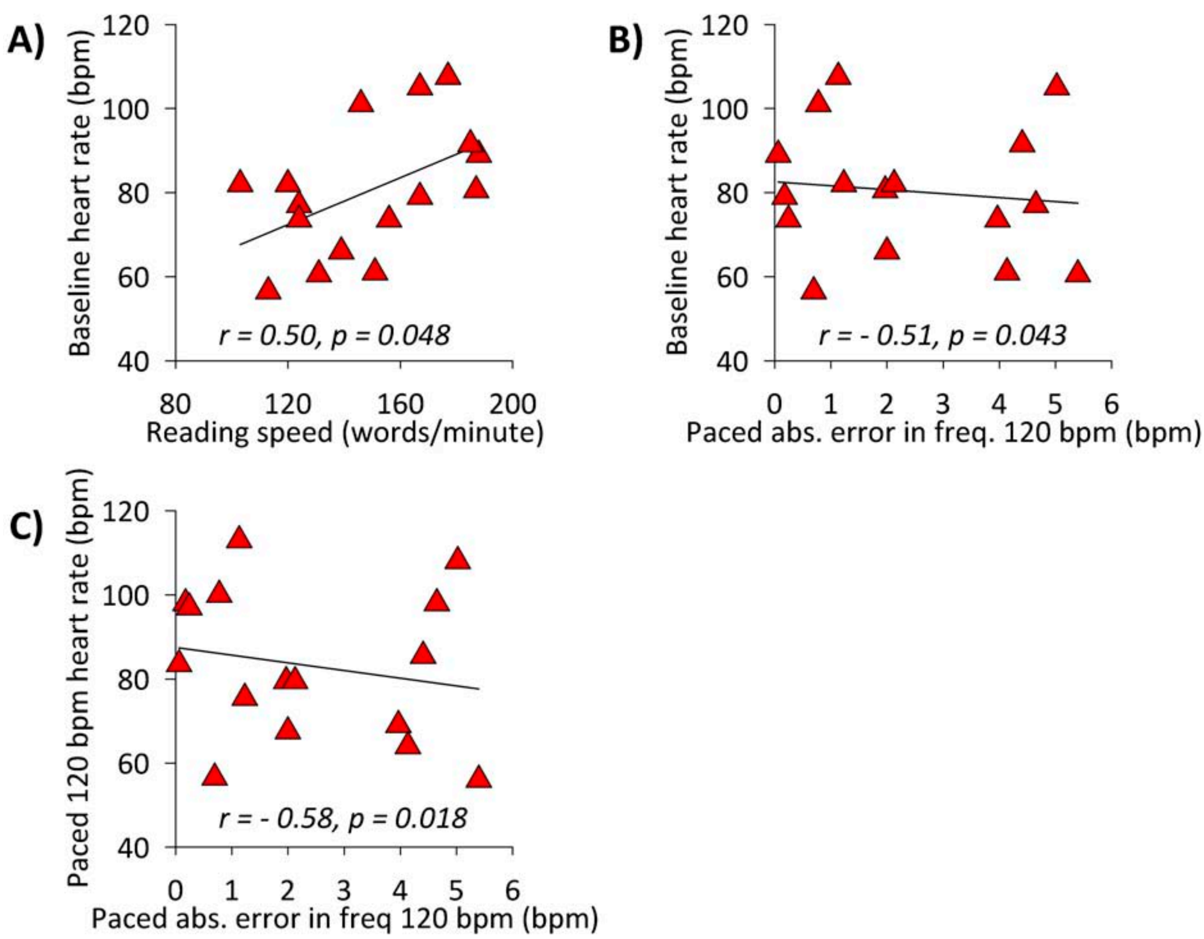

Figure 3.14: Scatter plots for significant correlations of heart rate measurements corresponding with reading performance, tapping performance, and beat perception performance dependent variables in the post-test. Correlation coefficients and *p*-values are provided for each significant correlation.

In the post-test, heart rate was not significantly correlated with any reading, unpaced tapping or beat perception variables (all *p*'s > 0.05; see Appendix H Section 7.8.2). However, reading speed was positively correlated with baseline heart rate (r = 0.50, p = 0.048), i.e. faster readers had a faster heart rate at baseline (Figure 3.14A). In addition, absolute mean error in tapping frequency during the paced tapping task at 120 bpm was negatively correlated with heart rate at baseline (r = -0.51, p = 0.043) and during the paced tapping task at 120 bpm (r = -0.582, p = 0.018), i.e. participants who were better at matching the 120 bpm frequency during the paced tapping task had a higher heart rate at baseline and during the paced tapping task at 120 bpm (Figure 3.14B & C).

3.6.2. Correlations of questionnaire responses and corresponding dependent variables in the pre-test

The results of the correlation analyses of variables from the questionnaire concerning English (hours speaking English, and frequency of reading, listening to, and writing English) with the dependent variables from the pre-test for reading, and variables from the questionnaire concerning music and physical coordination (frequency listening to music, dancing, participating in sports, and ratings of sense of rhythm and physical coordination) with the dependent variables from the pre-test for tapping and beat perception performance, including *p*-values for significant correlations, are presented in Appendix H Section 7.8.3. The significant correlations in the pre-test for the questionnaire and the corresponding dependent variables are presented graphically in Figure 3.15.

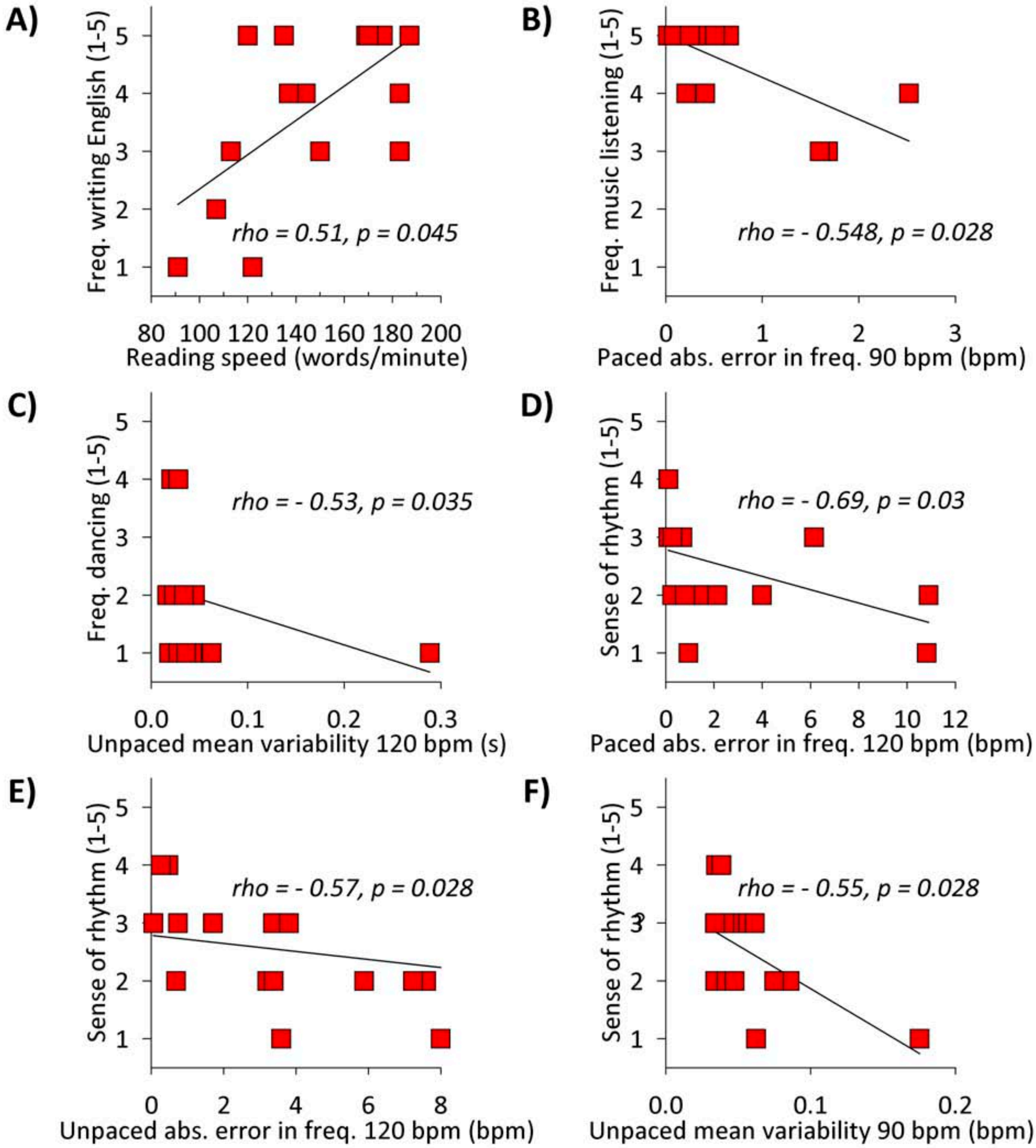

Figure 3.15: Scatter plots for significant correlations of variables from the questionnaire concerning English (hours speaking English, and frequency of reading, listening to, and writing English) with the dependent variables from the pre-test for reading, and variables from the questionnaire concerning music and physical coordination (frequency listening to music, dancing, participating in sports, and ratings of sense of rhythm and physical coordination) with the dependent variables from the pre-test for tapping and beat perception performance. Correlation coefficients and *p*-values are provided for each significant correlation. The questionnaire variables (y-axes) are ordinal scales of frequency (panels A-C; 1 = once per year or less, 2 = once per month, 3 = once per week, 4 = more than once per week, 5 = daily) or ordinal Likert scales (panels D-F; 1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = excellent).

The frequency of writing in English was positively correlated with reading speed (ρ = 0.506, p = 0.045), i.e. participants who reported writing in English more frequently were faster readers (Figure 3.15A). Furthermore, the frequency of listening to music was negatively correlated with absolute mean error in tapping frequency during the paced tapping task at 90 bpm (ρ = -0.548, p = 0.028), i.e. participants who reported listening to music more frequently were better at matching the 90 bpm frequency during the paced tapping task (Figure 3.15B). Additionally, the frequency of dancing was negatively correlated with the mean tapping variability during the unpaced tapping task at 120 bpm (ρ = -0.529, p = 0.035), i.e. participants who reported dancing more frequently were less variable at tapping during the unpaced tapping task at 120 bpm (Figure 3.15C).

Furthermore, sense of rhythm was negatively correlated with absolute mean error in tapping frequency during the paced (ρ = -0.691, p = 0.003) and unpaced (ρ = -0.574, p = 0.028) tapping tasks at 120 bpm, i.e. participants who evaluated their sense of rhythm to be higher were better at matching the 120 bpm frequency during the paced and unpaced tapping tasks (Figure 3.15D & E). Finally, sense of rhythm was also negatively correlated with the mean tapping variability during the paced tapping task at 90 bpm (ρ = -0.549, p = 0.028), i.e. participants who evaluated their sense of rhythm to be higher were less variable at tapping during the paced tapping task at 90 bpm (Figure 3.15F). There were no other significant correlations (all p's > 0.05; see Appendix H Section 7.8.3).

3.6.3. Correlations of training performance with reading, tapping, and beat perception performance variables

For the training group, there were no significant correlations between the rankings of participant performance during training with the percent changes in all dependent variables (reading, tapping, and beat perception performance) from the pre to post-tests (all p's > 0.05; see Appendix H Section 7.8.4).

4. DISCUSSION

As previously noted, the present study aimed to expand on the research by Tierney and Kraus (2013c) by investigating the relationship between tapping and reading abilities following a music training intervention. Half of the participants in the study completed the music training, while the other half functioned as a control group. The results from the study were analyzed in order to determine 1) if tapping and reading abilities correlate among ESL speakers, 2) if tapping and reading abilities improve after a music training intervention, and 3) if tapping and reading abilities mutually correlate with heart rate.

The results of the current study revealed that there were no statistically significant differences between the control and training groups from the pre to post-test, which requires acceptance of the statistical null hypothesis that there were no improvements in tapping, beat perception, or reading abilities for either group. There were, however, several statistically significant correlations between, for example, tapping and reading abilities, which support the results of previous research conducted by Tierney and Kraus (2013c). Although the differences between groups from the pre and post-test are not statistically significant, there are some trends, discussed below, which support the hypotheses of this study.

4.1. Questionnaire

The information collected by the questionnaire confirmed that the training and control groups were initially well matched for relevant variables in the present study (see Table 3.1). The information from the questionnaire was also utilized for determining whether the variables reflected on the questionnaire affected the participants' initial performance. Reading, tapping, and beat perception performance dependent variables in the pre-test were therefore compared with relevant variables on the questionnaire. The results revealed that the number of hours speaking English per week, frequency of reading English, and frequency listening to English did not correlate with any reading variables in the pre-test. In addition, the perceived level of physical coordination and frequency of sports participation did not correlate with any tapping or beat perception performance variables. It may therefore not be necessary to control for these variables in future studies.

However, the frequency of writing in English did positively correlate with reading speed. In addition, the reported frequency of listening to music, dancing, and sense of rhythm correlated with at least one tapping performance variable. This indicates that it is important for these variables to be evenly matched between groups prior to an intervention, and future studies could utilize these results by tailoring recruitment based on, for example, reported frequency of listening to music and dancing, in order to ensure that initial abilities between groups are similar. Furthermore, with a larger sample size in future studies, it is even more likely that these variables would be evenly matched between training and control groups prior to a training intervention.

While the Likert scale provided a useful method of measuring perceived ability, the temporal measurements could be improved in future studies. The options were specifically worded so as to avoid confusion that could adversely affect results, however, some participants declared that their answer was more realistically placed in-between two of the options (for example, more than once per week, but less than daily). In such instances, participants were asked to estimate which option was closest to their answer; however, future studies may require more options for temporal measurements.

4.2. Tapping performance

The results of the tapping performance were highly varied, contrary to expectations of the hypothesis. It was assumed that, having gained experience with tapping performance from the pre-test, all participants would their improve tapping performance in the post-test, and that the training group would improve more than the control group. The training group did improve more than the control group according to the following calculations: absolute mean difference of paced tapping at 90 and 120 bpm, mean variability of paced tapping at 90 and 120 bpm, absolute mean difference of unpaced tapping at 90 bpm, absolute error of unpaced tapping at 90 and 120 bpm, and mean variability of unpaced tapping at 120 bpm. However, none of the differences were statistically significant. In addition, there were examples of greater improvement among the control group than the training group in some tapping conditions, according to the following calculations: absolute error of paced tapping at 90 and 120 bpm, and absolute mean difference of unpaced tapping at 120 bpm. There was also one condition where tapping performance decreased among both groups, revealed in the calculation for mean variability of unpaced tapping at 90 bpm.

The variety of these results poses a challenge for deciphering conclusions regarding tapping ability after the music training intervention. It is also difficult to draw conclusions due to the variations of initial tapping ability between the training and control groups, evident in the pre-test. If the abilities were evenly matched between groups in the pre-test, the results of the post-test may be more obvious. Nevertheless, it is still possible to identify trends in these results, even if they are not statistically significant. For example, the training group improved more than the control group at eight of the tapping conditions after the music intervention, whereas the control group only improved more than the training group at three of the tapping conditions. The observation that training group participants demonstrated an improvement in tapping performance across more conditions than the control group may be attributed to the music training intervention.

In addition, the calculations for mean variability revealed a difference between the control and training groups that was not statistically significant, but was notable compared to the other calculations. These revealed that proportionally compared to the control group, the tapping performance of the training group across all conditions was less variable between the pre and post-test. These results indicate that the effect of the music training may have influenced participant ability to tap a steady beat more than the ability to tap together with an external beat (e.g. metronome).

The lack of statistically significant differences of tapping abilities between groups from the pre to the post-test may be attributed to several factors. The relatively low sample size in the current study may be responsible for the varied tapping abilities between groups, which the calculations from the pre-test revealed. Having a larger sample size would increase statistical power and help to ensure that the control and training groups reflect similar tapping abilities in the pre-test. This would enable differences after a music training intervention to be more clearly observed in the post-test.

Furthermore, access to a more accurate tapping test program such as the in-house test developed by Tierney and Kraus (2013c) would help to procude more precise results. Audacity was a sufficient subsitute program for this pilot study, however, there were several disadvantages. If the sounds of the tapping and the metronome clicks occurred near simultansiouly and their waveforms overlapped in the program, it was sometimes difficult to measure the exact timing of the tapping. In such instances, the measurement was estimated, and may reflect inaccuracies of approximately one millisecond. There were also instances where participants missed a tap, either because they were ahead or behind the tempo, or they simply skipped the tap. In order to complete calculations for the analysis of 20 sound presentations per trial in this study, these missed taps were replaced with a calculated average from the previous and subsequent taps. However, it would be more ideal in future studies to utilize a computer program with the ability to more precisely measure the accuracy of tapping.

In addition, the accuracy of tapping results could also be improved by affording more attention to the sounds produced by the metronome clicks and the tapping pad. Several training participants in this study who had difficulty tapping together with the metronome in the pre-test indicated that they became confused when the sound of their tapping aligned with the metronome in the post-test because they could not hear the difference between the sounds. This may have affected some of the tapping results of the training group in the post-test. Although the sounds of the rhythm pad and the metronome in this study were distinctive enough that they produced different waveforms in Audacity, it would be beneficial to more carefully consider the different sounds produced by the tapping apparatus and metronome clicks for any future studies.

4.3. Beat perception performance

The results from the beat perception test indicate that beat perception abilities between the training and control groups remained similar between the pre and post-tests. However, when taking confidence levels into consideration, the results between the pre and post-tests were more varied. Compared to the pre-test and compared to the control group, the training group provided more correct answers combined with a completely certain confidence level in the post-test. Not only did the training group become more confident of their correct answers, but their confidence of incorrect answers also decreased in the post-test. These results indicate that the training group became more confident in their perception of beat after the music training intervention.

Because the beat perception portion of this test was utilized from an existing beat synchronization test (the BAT), there were no difficulties with the practical application of this portion of the test. It was sometimes necessary to remind participants not to move while listening to the music, but this was also an issue for the creators of the BAT, who found that “many participants reported that it was difficult not being allowed to move rhythmically during the perception test" (Iversen & Patel, 2008, p. 466). Considering that there were no significant correlations between reading accuracy and beat perception, it may not be necessary to include this portion of the test in future studies. The inclusion of beat perception in this study, however, has provided evidence which supports notion that active (tapping) beat abilities are perhaps more relevant than passive (listening) beat abilities in relation to reading fluency.

4.4. Reading performance

The reading performances for each participant in the pre and post-tests were assigned a separate score for the following three conditions: reading speed, reading accuracy, and reading comprehension. The scores for reading speed and reading comprehension for both groups were similar in the pre and post-test. The reading accuracy scores were also similar in the pre and post-test, with a 1.09% increase in the training group and a 1.14% decrease in the control group. However, the individual scores in each group revealed that five participants in the training group improved their reading accuracy scores between the pre and post-test, compared to only one participant in the control group. The differences of the scores between the pre and post-tests were not statistically significant, but the fact that more training group participants increased their scores indicates a trend that the participants who received music training were more likely to increase their reading accuracy scores. The three training participants whose reading scores stayed the same or decreased may indicate that music training is not an effective method for enhancing reading performance among all individuals, perhaps due to differences of intelligence (Gardner, 1993). Nevertheless, the trends observed in these results warrant further investigation to clarify such ambiguities.

The lack of statistically significant results regarding reading abilities between groups from the pre to the post-test may be attributed to several factors. For example, the lack of more advanced reading levels and lack of reading comprehension questions among Reading A-Z's resources posed some complications. The mean reading speed of participants in the current study was actually below the target word per minute reading rate prescribed by Reading A-Z for 9-11 year olds (see Figure 3.10), which may indicate that the level was appropriate for the participants in the present study. However, 14 out of 16 participants scored over 90% in reading accuracy in the pre and post-tests, which may indicate that the level was too easy, leaving little room for improvement. Therefore, in future studies it would be beneficial to more precisely calibrate the level of readings to the age and education level of participants. In addition, it would be more ideal for the assessment of the readings to be marked by two independent examiners blinded by the hypotheses of the study, producing an average of the two scores, in order to remove potential for unbiased grading.

It would also be beneficial in future studies to more meticulously assess reading comprehension, which only consisted of five questions and three possible answers for each question in the current study. In addition, the readings available for this study were non-fiction, which left open a possibility that participants had prior knowledge related to the content of the reading. One of the readings, titled *Against the Wind*, contained a short history of Beryl Markham, who was the first woman to fly solo from east to west across the Atlantic Ocean. The other reading, titled *Picture This*, explained the basic principles of photography and operational functions of a camera. If participants happened to be knowledgeable about these topics, the results of their reading comprehension scores may have been affected, regardless of their reading accuracy.

Furthermore, reading fluency is a very difficult skill to measure empirically, even with the tests utilized by Tierney and Kraus (2013c). The methods utilized in the current study were rather crude, simply marking missed words as errors, when reading fluency is in reality much more complex, also involving, for example, prosody. An attempt to gauge prosodic features was therefore made following the completion of current study, by analyzing the recorded reading performances with Praat (Phonetics Sciences, Amsterdam, praat.org), a scientific speech analysis computer program. This program was used to objectively analyze the frequency (pitch) and intensity (dynamic) ranges of each reading performance, and those with a larger range of frequency and intensity were considered more prosodic than monotone. When these values were compared to reading accuracy scores, however, no significant correlations were found (see Appendix I). This does not disprove the importance of prosody and reading accuracy, but rather indicates that prosody cannot be crudely equated with a larger frequency and intensity range. Prosody is unfortunately a very difficult skill to measure objectively, but is definitely an area worthy of consideration for inclusion in future studies dealing with reading fluency.

There is one more consideration that may increase the potential for significant results in future studies, which involves recruitment criteria for the participant panel. The results from the current study indicate that participants with the lowest scores in the pre-test had the greatest potential for improvement in the post-test. However, even though English was a second language for all the participants, many of them nevertheless started with relatively high reading accuracy scores in the pre-test, leaving little room for improvement in the post-test. It was therefore difficult to observe changes in the results between the pre and post-tests among the control and training groups. In order to increase potential for observing differences, future studies may benefit from less advanced readers who start with lower reading accuracy scores in the pre-test.

4.5. Correlations of reading performance with tapping and beat perception performance

Reading speed and accuracy was significantly correlated in both the pre and post-test, which indicates that both of these variables are important aspects of overall reading fluency. In addition, reading accuracy was significantly correlated with reading comprehension in the post-test, which supports the findings of previous reading fluency studies (Hudson et al., 2005). These results confirm the importance reading speed, accuracy, and comprehension as overall indicators of reading fluency.

While all reading variables were not significantly correlated with all tapping (paced and unpaced) and beat perception variables in the pre-test, there were four significant correlations indicating that participants who were better at tapping were also better readers. Furthermore, there were no significant correlations showing that better readers performed worse on any of the tapping or beat perception tasks.

Similarly, while all reading variables were not significantly correlated with all tapping (paced and unpaced) and beat perception variables in the post-test, there eight significant correlations indicating that participants who were better at the tapping and beat perception tasks were also better readers. Again, there were no significant correlations showing that better readers performed worse on any of the tapping or beat perception tasks. These findings therefore support the previous research by Tierney and Kraus which reported a significant correlation between tapping and oral reading abilities (2013c). Furthermore, these findings support the first hypothesis of the current study that tapping and reading abilities correlate among ESL speakers.

It is interesting to note that there were more reading performance dependent variables that were significantly correlated with tapping and beat perception dependent variables in the post-test compared to the pre-test. It cannot be conclusively determined that these results were primarily due to the music training intervention, because data from both control and training groups were included in order increase the sample size and therefore likelihood of finding statistically significant correlations. However, it is possible that the increase of correlations in the post-test are due to changes in training group performance after the music training intervention. Future studies with a larger sample size, and therefore ability to compare correlations between groups, is necessary to investigate this observation further.

4.6. Heart rate

Heart rate recordings were collected in both the pre and post-test in order to determine whether tapping and reading abilities mutually correlate with heart rate. However, heart rate was not significantly correlated in the pre-test with any reading, unpaced tapping, or beat perception variables. The only significant heart rate correlations were found in the post-test, which revealed that participants who were better at matching the 120 bpm frequency during the paced tapping task had a higher heart rate at baseline and during the paced tapping task at 120 bpm. In addition, participants with a higher baseline heart rate also had a faster reading speed. This indicates that heart rate may correlate with tapping and reading performance, however, this relationship was not evident among all the tapping and reading tasks.

The lack of statistically significant heart rate correlations may be attributed to the absence of continuous heart rate recordings in the current study. Nevertheless, the statistically significant correlations that were found in the present study provide justification for further investigation. Future studies with access to equipment that can record and save heart rate measurements continuously may potentially uncover more significant relationships involving the entrainment of heart rate, rhythmic movement, and reading speed (Phillips-Silver, Aktipis, & Bryant, 2010). Considering the significant correlation between reading speed and reading accuracy, evidence of heart rate entrainment with reading speed may, by extension, result in a correlation between heart rate and reading accuracy. If future studies are also able to identify a correlation between heart and tapping performance, such heart rate data may therefore further illuminate the relationship between music and language abilities.

4.7. Training

All participants completed the required training within the allotted time frame, however, as previously noted, an extended time frame would be beneficial for future studies. It is probable that effects of music training could be more clearly observed if training were extended over a longer period of time.

In addition, it is possible that the effects of music training might be more clearly observed if participants engaged fully with singing activities. Not only is singing an activity that requires kinesthetic beat synchronization skills, but singing is in fact suspected to be a particularly useful tool for learning a second language (Swaby, 2015). This notion is supported by the premise that singing experience enhances the development of fine motor and auditory skills required for mastering nuances of varying pronunciation, which is a particularly relevant concern for students learning a second language (Mora, 2000). However, it must be reiterated that maintenance of a safe and comfortable learning environment is paramount. Future studies with more time may have the opportunity to successfully encourage more participants to become comfortable with the prospect of engaging with singing as a part of the music training intervention.

In order to determine whether reduced piano training time among some participants influenced the dependent variables from the pre to post-tests, rankings of performance ability during training were correlated with the percent changes in all dependent variables. The results revealed that training performance ranking did not correlate with any of the changes in reading, tapping, or beat perception performance variables from the pre to the post-test. This indicates that participants who demonstrated superior performance during training and therefore received more piano training time did not necessarily improve the most (or the least) compared to other training participants between the pre and post-test. However, the method of rating was subjectively based on piano training time, and could be improved in future studies. For example, objectivity could be increased if an independent educator blinded to the study objectives carried out the music training and any potential training performance assessments. Nevertheless, these results indicate that learning outcomes surrounding beat synchronization were not adversely impacted due to reduced piano training time, which supports the decision to tailor training time to the needs of the individual participants.

4.8. Additional considerations

As previously outlined, all participants were recruited on the basis that English was not their native language and that they did not have an extensive history of music training. These conditions were selected in order to investigate the effects of beat training on ESL abilities, but also to allow maximal room for improvement between the pre and post-test. As noted, however, many of the participants in this study received relatively high reading accuracy scores in the post-test.

The hypotheses of this study were concealed from all participants until they completed the study so as to avoid potential bias in their test performance; however, discussions about the hypothesis with participants following completion of the study yielded some relevant information regarding participant ability. For example, some participants indicated a particular interest for having the opportunity to learn about music, which they had been previously prevented from for various reasons such as time and cost. Their interest in the material of this study affected their motivation for participating, which may partially explain some of the high scores.

In addition, after completion of the study, one participant revealed their prior history of experience as a DJ. This information was not evident on the questionnaire, because the participant did not consider his experience as a DJ as a form of music training. However, DJ experience undoubtedly influenced this participant's performance in this study, which is evident in the results of the beat performance of the test; they were they only participant to receive a perfect score. In addition, two other participants revealed after completion of the study that they have semi-regular experience as participants in the Aalborg Shakespeare Company, where they have gained experience reading English texts aloud. Again, this specific information was not filtered by the questionnaire, but was a relevant factor likely to influence reading performance. In order to ensure maximal potential for improvement, future studies would benefit from carefully selecting participants whose oral reading and beat synchronization abilities are limited.

These specific examples of participants in this study reiterate the fact that beat and reading abilities are not solely codependent, nor are beat and music abilities. Beat training can occur outside of traditional music training, and reading abilities can be developed without beat training. However, as the results from this study indicate, reading abilities are correlated with activate beat performance (tapping) more than listening (beat perception). Therefore, while music training is not the only medium for developing beat and reading skills, it seems to be an effective medium for training active beat skills, and this is the relevant skill set that has been reported to correlate with reading performance, as reported by previous research by Tierney and Kraus (2013c) in addition to the current study.

4.9. Future research

Although the results of the differences between the pre and post-test in the current study were not statistically significant, there were trends which indicate that music training has the potential to influence ESL reading fluency. The results may therefore be reflective of a type I statistical error, or a false positive which incorrectly accepts the null hypothesis. This potential error could be challenged in future research with access to additional resources and the capacity to refine the methodological procedures that have been tested in the current pilot study, thereby increasing the potential for statistically significant evidence.

Some of the suggestions for future research included in the discussion so far have included a larger participant base and extended training time that includes singing training. In addition, future studies could benefit from precise methods of assessing tapping and reading ability, potentially including some form of assessment for prosodic features. The questionnaire could also be more concise, focusing on variables that were significantly correlated with the dependent variables in the current study, and it could also be used to ensure an initially lower baseline ability among participants to enable maximal potential for improvement between pre and post-tests. Furthermore, a method of continuous heart rate measurement may increase potential for results reflecting entrainment of heart rate, tapping, and reading performance.

With access to such resources outline above, the increased potential of statistically significant results could also enhance examination of the differences between the tapping conditions (paced, unpaced, 90 bpm, 120 bpm). Due to the lack of such resources, and the subsequent variability of the results, these conditions were not directly compared in the current study.

Future studies may also consider investigating the relationship between various native languages and tapping ability, considering the research that has reported a relationship between speech and music patterns among composers (Patel et al., 2006). This was not investigated in the current study due to the variety of languages included, which resulted in a limited sample size for the languages represented and was therefore not conducive for finding statistically significant results. Future studies may investigate this area further by including only a small number of languages that are each represented by a substantial sample size.

Furthermore, future studies could also benefit from a retention test. The observed trends in the current study indicate that adults, not only children (Slater et al., 2013), are susceptible to the cognitive effects of music training. However, it would be beneficial to investigate if such effects are retained. With a longer period of time available for testing, two pre-tests could be conducted in order to ensure that the initial baseline measurements among the control and training groups are stable and not due to sampling error. Then, after an extended training period, two post-tests could be conducted over a period of time. For example, one post-test could be administered immediately following the training period and the retention test could be administered one month later. This would enable determination of whether any observed changes are transient or long lasting.

5. CONCLUSION

Discussions surrounding the value of music education started at least 2,000 years ago and they continue to the present day. The forum for such discussion, however, has changed dramatically. Convincing arguments could once be solely made thorough philosophical reasoning and rhetoric, which continue to be valuable mediums of debate. There are indeed plenty of passionate points that can be conveyed regarding the purely aesthetic value of music, which can and should be appreciated. Today, however, the modern scientific community has the ability to contribute significantly to discussion. The advancements in research technologies have enabled an increased amount of empirical evidence surrounding many fields, including music education, which has become highly valued in the contemporary forum for discussion. When discussion turns to debate as a result of, for example, economic and political stress, such empirical evidence has the particularly powerful potential to sway modern opinion.

It has therefore become increasingly important to provide tangible verification of the benefits of music education that have long been suspected, in order to promote the importance of state-funded music programs among contemporary policy makers who value empirical evidence. Thus far, such evidence has uncovered details about the complex cognitive demands of music performance and the resulting implications (Barrett et al., 2013). The cognitive processing areas enhanced by music training are not exclusive to musical ability, which is why music training has been credited with enhancing areas unrelated to music, such as linguistic ability (Tierney & Kraus, 2013b).

The purpose of the current study has been to expand on such research in order to contribute to the forum for debate surrounding the value of music education. In order to further investigate this field of study, a pilot study was designed with the aim of investigating 1) if existing music and linguistic correlations extend to ESL reading abilities, 2) if a music training intervention affects reading fluency skills between a pre and post-test, and 3) if there are any physiological responses that correlate between music and language tasks.

Possibly due to a number of methodological deficiencies that may have adversely affected the results, no statistical differences between a pre and post-test after the music training intervention were identified. However, a number of trends were observed which provide justification for further research. The results of the study indicated that, following a music training intervention, the training group improved at tapping performance in eight of the tapping conditions, compared to only three tapping conditions that were improved in the control group. In addition, the training group increased their confidence of beat perception compared to the control group. These results may be attributed to the music training intervention, which focused on beat synchronization abilities.

The indication that music training improved beat synchronization abilities among training participants in the current study supports the efficacy of the educational theory that was referenced for the design of training sessions. The primary purpose of the current study, however, was to investigate whether or not this music training also affected ESL reading fluency abilities. The results were not statistically significant, however, there were five times as many training group participants who increased their reading accuracy between the pre and post-test than control group participants. These results indicate that music training likely has a positive influence on reading fluency skills, which is worth investigating further in future studies with access to greater resources.

Despite the lack of statistically significant differences between the pre and post-test, there were a number of statistically significant correlations found in the results. Most notably, a number of significant correlations between tapping ability and reading performance were found, which partially support the results of previous research conduced by Tierney and Kraus that inspired justification for the current study (2013c). Furthermore, there were twice as many statistically significant correlations of reading performance dependent variables with tapping and beat perception dependent variables in the post-test compared to the pre-test. Data from both the training and control group were included in these correlations in order to increase the statistical power, so it is not possible to conclusively determine the cause for the twofold increase of significant correlations in the post-test. However, it is possible that the music training intervention influenced the performance of the training group, which resulted in the increase of significant correlations in the post-test. Further research is required to investigate this trend.

There was also a total of three (out of a possible 96) statistically significant correlations discovered between tapping performance dependent variables and heart rate recorded at baseline and during the tapping tasks, or between reading performance dependent variables and heart rate recorded at baseline and during the reading task. The low amount of statistically significant correlations does not provide sufficient evidence for drawing conclusions about the relationship between heart rate and tapping performance, or heart rate and reading performance. However, the result of three statistically significant correlations provides justification for further research in this area. Data collected from more sophisticated heart rate recording equipment may reveal an increased number of statistically significant correlations that could provide insight regarding heart rate and potential entrainment with tapping and reading speeds.

In summary, a number of significant correlations between tapping, reading, and beat perception performance were identified, providing evidence in support of the first hypothesis of this study that music and ESL language reading abilities are correlated. However, due to a low amount of statistically significant data, there was a lack of support for the hypotheses that music and reading abilities would improve after a music training intervention and that heart rate would mutually correlate with music and language tasks. Nevertheless, further research is justified by the trends observed in the current study, which indicate that music training has the potential to decrease variability in tapping performance, increase confidence of beat perception, and increase reading accuracy. These trends were observed despite deficiencies in methodological procedures. Future studies with access to greater resources and therefore refined methodological procedures may possess increased potential for finding statistically significant results to support the relationship between music cognition and linguistic fluency.

The results of the current study contribute to the ongoing discussion surrounding the value of music education by providing evidence in support of previous studies that have reported a correlation between musical and linguistic abilities (Tierney & Kraus, 2013c), and by extending the application of this evidence to second language abilities. Furthermore, the results of the current study contribute to the discussion surrounding the value of music education by providing legitimate justification for continued research in this field. Based on the trends observed in the present study, such future research has the potential to continue the advancement of empirical knowledge in support of the ancient philosophy that there are indeed patterns in music that provide keys to other areas of learning.

6. References

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7. APPENDICES

7.1. Appendix A

7.1.1. Consent release form

AALBORG UNIVERSITY
DENMARK

Music and Language Study

Participant Consent Form

- I understand the purpose of the research project and my involvement in it.
- I agree to take part in the research project.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I understand that I will be audiotaped during the study.
- I understand that physiological data will be gathered (heart rate).
- I understand that, while information gained during the study may be published, I will not be identified and my personal data will remain confidential.
- I understand that I may contact the researcher or supervisor if I require further information about the research.

Signed ______________________________ (research participant)

Print name ______________________________ **Date** ______________

Contact details

Researcher:
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26 37 39 37

Supervisor:
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99 40 91 00

7.2. Appendix B

7.2.1. Questionnaire

Music and Language Study Questionnaire

Please respond to the following questions and check the circles that are most appropriate

1. Name: ____ Date: ______________________

2. Gender: ◯ Male ◯ Female

3. Age: _______ years

4. Dominant hand: ◯ Left ◯ Right

5. What is your nationality? ____

6. What is your native language? ____

7. Besides your native language, do you speak any other languages fluently? ◯ Yes ◯ No

If yes, please specify: ____

8. What is the highest English exam that you have completed? ______________________

9. What is your highest level *and* field of education? ______________________________

10. Have you completed your education? ◯ Yes ◯ No

If yes, please specify your current occupation: ______________________________

11. What kind of activities do you participate in that allow you to speak English and how often do you attend? (*Examples: English class once per week, work everyday, socializing with international friends twice per week, etc.*):

____

____

Please estimate the total number of hours you speak English per week: ______________________

12. Do you read in English?

◯ Once per year or less ◯ Once per month ◯ Once per week ◯ More than once per week ◯ Daily

13. Do you listen to English (radio, television, etc.)?

◯ Once per year or less ◯ Once per month ◯ Once per week ◯ More than once per week ◯ Daily

14. Do you write in English?

◯ Once per year or less ◯ Once per month ◯ Once per week ◯ More than once per week ◯ Daily

15. Do you have any documented reading problems? ◯ Yes ◯ No

If yes, please specify: ____

16. Do you have any documented hearing problems? ◯ Yes ◯ No

If yes, please specify: ____

17. Do you have any documented learning impairments or neurological disorders? ◯ Yes ◯ No

If yes, please specify: ____

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18. Do you listen to music?

○ Once per year or less ○ Once per month ○ Once per week ○ More than once per week ○ Daily

19. Do you dance?

○ Once per year or less ○ Once per month ○ Once per week ○ More than once per week ○ Daily

20. How would you rate your overall sense of rhythm?

○ Very Poor ○ Poor ○ Average ○ Good ○ Excellent

21. In general, how would you rate your physical coordination?

○ Very Clumsy ○ Clumsy ○ Average ○ Good ○ Excellent

22. How often do you participate in sports or other physical activities?

○ Once per year or less ○ Once per month ○ Once per week ○ More than once per week ○ Daily

Please specify the type of sports or activities, if applicable: ________________________________

23. Do you have any musical training? If not, you are done! ○ Yes ○ No

23a. Please list what kind of training (for example, instruments, choir, etc.) you have received and for how many years:

____

____

23b. Do you still receive musical training?

Yes. → Which instrument or activity (and how many hours per week do you practice)?

____(______________)

No. → How long ago did you stop? ____________________

Thank you for completing the questionnaire!

7.3. Appendix C

7.3.1. Reading 1: Against the wind

Reading A-Z

LEVEL Z

Fluency Passage–Nonfiction

Against the Wind

Name ____________________________

Word Count: 299

Against the Wind

Although Beryl Markham was born in England, she 8
grew up and spent a majority of her life in Africa. She 20
was a famous racehorse trainer when she became 28
enchanted with the thought of flying planes. 35

Markham began taking flying lessons, and after only 43
eight hours of lessons, she flew her first solo flight. She 54
went on to earn her pilot's license, which allowed her to 65
carry passengers in her plane. Markham delivered mail 73
and supplies in her plane and flew sick patients to the 84
hospital. She flew thousands of miles over African jungles. 93
A pilot friend called her "a fine pilot with great courage 104
who could find her way in a plane to any spot." 115

Markham soon decided to strive for something no woman 124
had yet accomplished—flying solo across the Atlantic from 133
east to west. Amelia Earhart had made a solo flight across 144
the Atlantic from west to east with the wind behind her 155
plane. Markham wanted to fly in the opposite direction with 165

Name ______________________________ Word Count: 299

the winds against her, making the crossing lengthier and 174
much more dangerous than Earhart's flight. 180

In 1936, Markham took off from England in a plane 190
with no radio. Soon after she left England, however, the 200
wind swept her map out of her hands and into the ocean. 212
She flew "blindly" for 19 hours through darkness and 221
stormy weather. 223

At one point, as the weather got worse and lightning 233
flashed, Markham realized that she was flying upside 241
down. She was able to turn the aircraft right side up. 252
Finally, when a fuel line froze, Markham crash-landed 260
in Nova Scotia, Canada. She did not fly all the way from 272
England to America, according to her original plan. 280
However, Markham became the first woman to make 288
a solo nonstop flight from east to west across the Atlantic. 299

Number of Errors	1	2	3	4	5	6	Accuracy (%):	

Reading Rate (Words Per Minute):

TARGET

100 110 120 130 140 150 **160** 170 180 190 200 210 220

7.3.2. Reading 2: Picture this

Reading A-Z LEVEL Z

Fluency Passage–Nonfiction

Picture This

Name ______________________________ Word Count: 299

Picture This

Imagine that you are sitting in a darkened room that has a 12
tiny round window, barely the size of a quarter. The window 23
allows some light to enter, perhaps from a moonlit forest, 33
casting an image of trees on the wall opposite the window. 44
This is the basic principle on which a camera operates. 54

A camera consists of three main elements that are similar 64
to the parts of a human eye. All cameras contain a device 76
called a *shutter.* The shutter allows light to enter the camera, 87
just as you use your eyelids to let in or shut out light. On 101
some cameras, photographers control the amount of light 109
by altering the length of time the shutter remains open. 119

These cameras have a diaphragm, which also controls 127
the amount of light entering the camera. The diaphragm 136
is like the iris of your eye, which expands or contracts 147
to limit the amount of light entering it. 155

Page 1 of 2

www.readinga-z.com

Name ____ Word Count: 299

Light that enters a camera passes through a curved piece 165
of glass or plastic that bends and focuses the light onto the 177
film. This curved piece is called the *lens,* and unlike the lens 189
of a human eye, it cannot alter its shape. In some cameras, 201
the lens can be moved in and out to focus an image on the 215
film. The lens is moved inward to focus on distant objects 226
and outward to focus on objects that are close. 235

A camera lens causes rays of light to narrow and then 246
create images on film. Because the light bends, the image 256
is upside down. This is similar to the lens of a human eye, 269
which registers as upside down an image that is corrected 279
by the brain. In a camera, the image is stored on film and 292
is corrected when the film is developed. 299

Number of Errors

1	2	3	4	5	6

Accuracy (%): ________

Reading Rate (Words Per Minute):

TARGET

100 110 120 130 140 150 **160** 170 180 190 200 210 220

7.4. Appendix D

7.4.1. Reading comprehension questions

Reading Comprehension Questions

Against the Wind

1. Beryl Markham was born in Africa. (False)
2. Markham delivered mail and supplies in her plane and flew sick patients to the hospital. (True)
3. Markham's crossing over the Atlantic was safer than Amelia Earhart's. (False)
4. Markham's plane was equipped with a radio. (False)
5. Markham became the first woman to make a solo nonstop flight from east to west across the Atlantic. (True)

Picture This

1. The start of the reading asks you to imagine that you are sitting in a darkened room that has a square window the size of a dollar. (False)
2. A camera consists of three main elements that are similar to the parts of a human eye. (True)
3. The diaphragm of a camera controls the amount of light entering the camera. (True)
4. A camera lens is moved inward to focus on distant objects and outward to focus on objects that are close. (True)
5. The lens of a camera registers an image as right side up, unlike the lens of a human eye. (False)

7.5. Appendix E

7.5.1. Data collection form

Music and Language Study Data Collection Form

Participant Name: ______________________________________Date: __________________

Reminders: close irrelevant computer programs; open Audacity and iTunes; randomize tempos, track times and reading; make sure volume on iPad and Computer is all the way up and they are placed on tape; place do not disturb sign on door

Circle One: Pre-Test / Post-Test

Baseline heart rate page 1 questionnaire	
Baseline heart rate page 2 questionnaire	

Section 1: Rhythm

Task 1: Paced tapping

Beeps from computer – as soon as you hear them, start tapping along to the beat on the drum pad. Continue tapping until the beeps stop. There will be 4 trials total.

	Tempo	Heart rate	Completed
Trial 1			
Trial 2			
Trial 3			
Trial 4			

Task 2: Unpaced tapping

Beeps from computer – as soon as you hear them, start tapping along to the beat on the drum pad. The beeps from computer will stop but please continue tapping at the same pace. Continue tapping until I ask you to stop. There will be 4 trials total.

	Tempo	Heart rate	Completed
Trial 1			
Trial 2			
Trial 3			
Trial 4			

Task 3: Beat perception, **playlist option #** ____________

Listen to the music and decide if the beeps are on or off the beat. ***Don't tap or move along****. When the music stops, give your answer. There will be 18 trials total.*

	Track number	Participant Answer Y = On Beat N = Off Beat	Participant Confidence 1 = Guessing 2 = Somewhat sure 3 = Completely certain
Trial a			
Trial b			
Trial c			
Trial d			

Trial e			
Trial f			
Heart rate			
Trial g			
Trial h			
Trial i			
Trial j			
Trial k			
Trial l			
Heart rate			
Trial m			
Trial n			
Trial o			
Trial p			
Trial q			
Trail r			
Heart rate			

Y = On Beat, N = Off Beat; 1 = Guessing, 2 = Somewhat sure, 3 = Completely certain

Section 2: Reading

Reading title: ____

Task 1: Reading aloud

Read the text aloud. If you have trouble reading a word (struggling for 3-5 seconds) I will say the word so you can continue reading. After you finish, I will take the text away and ask you five questions about the text.

Turn heart rate monitor and START Recording

Start stopwatch (Clock time)	*Heart rate at start*	**Word after 1 minute**	***Heart rate after 1 minute***	**Stop** Stopwatch time	*Heart rate at stop*

STOP Recording

Task 2: Reading comprehension (can answer true, false, or don't know)

	Participant answer: T/F/D(on't know)
Question 1	
Question 2	
Question 3	
Question 4	
Question 5	
Heart Rate	

Notes:

7.6. Appendix F

7.6.1. Training lesson plan

Training Lesson Plan

Time

- 1 hour

Materials

- Two sets of chopsticks
- Two bouncing balls
- Rope (20 cm with knot on each end)
- Metronome application

Music

- Lesson 1: Lightly Row
- Lesson 2: Cuckoo
- Lesson 3: French Children's Song
- Lesson 4: Goodbye to Winter

Activities

- Drumming
    1. Tap the beat of folksong with chopstick
    2. Tap the melody of folksong with chopstick
    3. Tap the beat of the folksong with non-dominant hand chopstick while simultaneously tapping the rhythm of the melody with dominant hand chopstick
- Dancing
    4. Walk in place to the beat of the folksong (one footstep per beat) and clap the rhythm of the melody with hands
    5. Walk in place to the beat of the folksong while played on the piano, stop walking and start clapping the beat whenever the music stops
    6. Bounce and catch ball to beat of the folksong *(sing?)*
    7. First participant bounces ball on beats one and three, second participant bounces ball on beats two and four* *(sing?)*
    8. Bounce one ball between each other, bounce on one and catch on two* *(sing?)*
    9. Simple choreography with steps and bouncing to folksong accompaniment
- Conducting
    10. Synchronized conducting with rope folksong accompaniment
    11. Follow and lead piano folksong accompaniment
- Piano
    12. Play folksong on piano, with eventual metronome accompaniment (ranging from 90 to 120 bpm)

---

* In ¾ time, partners take turns bouncing on beat one of alternate measures (then catch on beat two and hold on beat three)

7.7. Appendix G

7.7.1. Suzuki folksong 1: Lightly row

Lightly Row

ちょう ちょう

ドイツ民謡
German Folk Song
Chanson populaire
Volkslied
Canción Folklórica

Students may play this piece in unison also as "The Honeybee."

Doucement à l'Aviron ***Rudere sanft*** Remando Suavemente

7.7.2. Suzuki folksong 2: Cuckoo

7.7.3. Suzuki folksong 3: French children's song

French Children's Song

(Petit Papa)

こどもの歌

ドイツ民謡
French Folk Song
Chanson populaire
Volkslied
Canción Folklórica

Chanson des Enfants Français **_Französisches Kinderlied_** Canción de Niños Francesas

7.7.4. Suzuki folksong 4: Good-bye to winter

Good-bye to Winter

(Hiver, adieu!)

さようなら

ドイツ民謡
Folk Song
Chanson populaire
Volkslied
Canción Folklórica

Adieu à l'Hiver ***Winters Abschied*** Adios al Invierno

7.8. Appendix H

7.8.1. Correlation results for pre and post-test performance dependent variables

Table 7.1: Results of the correlation analyses of reading performance dependent variables with tapping and beat perception performance dependent variables for both the pre and post-tests, including p-values for significant correlations. Significant correlations are highlighted in yellow. Participants from the training and control groups are included in the correlations.

		Pre-Test		Post-Test	
Variable 1	**Variable 2**	**Correlation**	***P*-value**	**Correlation**	***P*-value**
Reading accuracy	Reading speed	.772	< .001	.663	.005
	Reading comprehension	.417		.532	.034
Reading speed	Reading comprehension	.195		.379	
Reading accuracy	Paced abs. mean diff. 90 bpm	-.051		-.440	
	Paced abs. mean diff. 120 bpm	-.090		-.031	
	Paced mean abs. error freq. 90 bpm	-.105		-.275	
	Paced mean abs. error freq. 120 bpm	-.229		.040	
	Paced mean variability 90 bpm	.125		-.530	.035
	Paced mean variability 120 bpm	-.511	.043	-.665	.005
Reading speed	Paced abs. mean diff. 90 bpm	-.276		-.285	
	Paced abs. mean diff. 120 bpm	-.425		-.201	
	Paced mean abs. error freq. 90 bpm	-.253		-.295	
	Paced mean abs. error freq. 120 bpm	-.485		-.159	
	Paced mean variability 90 bpm	.146		-.323	
	Paced mean variability 120 bpm	-.426		-.475	
Reading comprehension	Paced abs. mean diff. 90 bpm	.095		-.536	.032
	Paced abs. mean diff. 120 bpm	.183		-.432	
	Paced mean abs. error freq. 90 bpm	-.107		-.445	
	Paced mean abs. error freq. 120 bpm	.161		-.204	
	Paced mean variability 90 bpm	.271		-.550	.027
	Paced mean variability 120 bpm	.190		.223	
Reading accuracy	Unpaced abs. mean diff. 90 bpm	.046		-.464	
	Unpaced abs. mean diff. 120 bpm	-.103		-.080	
	Unpaced mean abs. error freq. 90 bpm	-.002		-.460	
	Unpaced mean abs. error freq. 120 bpm	-.367		.115	
	Unpaced mean variability 90 bpm	.431		-.156	
	Unpaced mean variability 120 bpm	-.551	.027	-.458	
Reading speed	Unpaced abs. mean diff. 90 bpm	-.244		-.424	
	Unpaced abs. mean diff. 120 bpm	-.542	.030	-.231	
	Unpaced mean abs. error freq. 90 bpm	-.253		-.587	.017
	Unpaced mean abs. error freq. 120 bpm	-.404		.014	
	Unpaced mean variability 90 bpm	.240		-.208	
	Unpaced mean variability 120 bpm	-.381		-.487	
Reading comprehension	Unpaced abs. mean diff. 90 bpm	.415		-.084	
	Unpaced abs. mean diff. 120 bpm	.320		-.630	.009
	Unpaced mean abs. error freq. 90 bpm	.443		-.373	
	Unpaced mean abs. error freq. 120 bpm	-.184		-.384	
	Unpaced mean variability 90 bpm	.263		-.122	
	Unpaced mean variability 120 bpm	-.532	.034	-.514	.042
Reading accuracy	Beat perception % correct	.301		.275	
	Beat perception % correct & confident	.085		.183	
	Beat perception rating correct answers	.028		.213	
	Beat perception rating incorrect answers	-.258		.165	
Reading speed	Beat perception % correct	.468		.165	
	Beat perception % correct & confident	.313		.312	
	Beat perception rating correct answers	.167		.323	
	Beat perception rating incorrect answers	-.128		.190	
Reading comprehension	Beat perception % correct	.155		.575	.020
	Beat perception % correct & confident	-.306		.283	
	Beat perception rating correct answers	-.412		.089	
	Beat perception rating incorrect answers	-.114		-.122	

7.8.2. Correlation results for pre and post-test heart rate measurements and dependent variables

Table 7.2: Results of the correlation analyses of heart rate measurements with corresponding reading performance, tapping performance, and beat perception performance dependent variables in the pre and post-tests, including *p*-values for significant correlations. Significant correlations are highlighted in yellow. Participants from the training and control groups are included in the correlations.

		Pre-Test		Post-Test	
Variable 1	**Variable 2**	**Correlation**	***P*-value**	**Correlation**	***P*-value**
Reading accuracy	Baseline heart rate	.250		.101	
	Reading start heart rate	.337		.165	
	Reading 1 minute heart rate	-.076		.232	
	Reading stop heart rate	.287		.160	
Reading speed	Baseline heart rate	.227		.502	.048
	Reading start heart rate	.277		.280	
	Reading 1 minute heart rate	.004		.443	
	Reading stop heart rate	.262		.482	
Reading comprehension	Baseline heart rate	-.330		.231	
	Reading comprehension heart rate	-.108		.234	
Paced abs. mean diff. 90 bpm	Baseline heart rate	-.286		-.184	
	Paced 90 bpm heart rate	-.226		-.135	
Paced abs. mean diff. 120 bpm	Baseline heart rate	-.030		-.410	
	Paced 120 bpm heart rate	.252		-.372	
Paced mean abs. error freq. 90 bpm	Baseline heart rate	-.156		-.418	
	Paced 90 bpm heart rate	-.132		-.410	
Paced mean abs. error freq. 120 bpm	Baseline heart rate	-.137		-.510	.043
	Paced 120 bpm heart rate	.128		-.582	.018
Paced mean variability 90 bpm	Baseline heart rate	-.245		-.251	
	Paced 90 bpm heart rate	-.165		-.101	
Paced mean variability 120 bpm	Baseline heart rate	-.138		-.075	
	Paced 120 bpm heart rate	-.373		-.174	
Unpaced abs. mean diff. 90 bpm	Baseline heart rate	-.209		.070	
	Unpaced 90 bpm heart rate	-.179		-.039	
Unpaced abs. mean diff. 120 bpm	Baseline heart rate	-.138		-.135	
	Unpaced 120 bpm heart rate	-.479		.124	
Unpaced mean abs. error freq. 90 bpm	Baseline heart rate	-.343		-.180	
	Unpaced 90 bpm heart rate	-.180		-.192	
Unpaced mean abs. error freq. 120 bpm	Baseline heart rate	-.316		-.115	
	Unpaced 120 bpm heart rate	-.363		-.094	
Unpaced mean variability 90 bpm	Baseline heart rate	.241		.346	
	Unpaced 90 bpm heart rate	-.081		.399	
Unpaced mean variability 120 bpm	Baseline heart rate	-.175		.058	
	Unpaced 120 bpm heart rate	-.215		.263	
Beat perception % correct	Baseline heart rate	.040		.046	
	Beat perception heart rate	.049		.048	
Beat perception % correct & confident	Baseline heart rate	.012		.122	
	Beat perception heart rate	.005		.089	
Beat perception rating correct answers	Baseline heart rate	-.017		.081	
	Beat perception heart rate	-.025		.052	
Beat perception rating incorrect answers	Baseline heart rate	-.358		.158	
	Beat perception heart rate	-.212		.157	

7.8.3. Correlation results for questionnaire responses and corresponding dependent variables in the pre-test

Table 7.3: Results of the correlation analyses of variables from the questionnaire concerning English (hours speaking English, and frequency of reading, listening to, and writing English) with the dependent variables from the pre-test for reading, and variables from the questionnaire concerning music and physical coordination (frequency listening to music, dancing, participating in sports, and ratings of sense of rhythm and physical coordination) with the dependent variables from the pre-test for tapping performance, including *p*-values for significant correlations. Significant correlations are highlighted in yellow. Participants from the training and control groups are included in the correlations.

Variable 1	Variable 2	Correlation	*P*-value
Hours speaking English/week	Reading accuracy	.098	
	Reading speed	.195	
	Reading comprehension	.081	
Frequency of reading English	Reading accuracy	.158	
	Reading speed	-.024	
	Reading comprehension	-.311	
Frequency listening to English	Reading accuracy	.019	
	Reading speed	.140	
	Reading comprehension	-.334	
Frequency writing English	Reading accuracy	.371	
	Reading speed	.506	.045
	Reading comprehension	.059	
Frequency of listening to music	Paced abs. mean diff. 90 bpm	-.436	
	Paced abs. mean diff. 120 bpm	-.234	
	Paced mean abs. error freq. 90 bpm	-.548	.028
	Paced mean abs. error freq. 120 bpm	-.302	
	Paced mean variability 90 bpm	-.272	
	Paced mean variability 120 bpm	-.308	
	Unpaced abs. mean diff. 90 bpm	-.482	
	Unpaced abs. mean diff. 120 bpm	-.396	
	Unpaced mean abs. error freq. 90 bpm	-.381	
	Unpaced mean abs. error freq. 120 bpm	-.219	
	Unpaced mean variability 90 bpm	.114	
	Unpaced mean variability 120 bpm	-.003	
	Beat perception % correct	.457	
	Beat perception % correct & confident	.272	
	Beat perception rating correct answers	.106	
	Beat perception rating incorrect answers	.039	
Frequency of dancing	Paced abs. mean diff. 90 bpm	.187	
	Paced abs. mean diff. 120 bpm	-.205	
	Paced mean abs. error freq. 90 bpm	-.052	
	Paced mean abs. error freq. 120 bpm	-.414	
	Paced mean variability 90 bpm	-.207	
	Paced mean variability 120 bpm	.278	
	Unpaced abs. mean diff. 90 bpm	.428	
	Unpaced abs. mean diff. 120 bpm	.040	
	Unpaced mean abs. error freq. 90 bpm	.336	
	Unpaced mean abs. error freq. 120 bpm	-.469	
	Unpaced mean variability 90 bpm	-.101	
	Unpaced mean variability 120 bpm	-.529	.035
	Beat perception % correct	.243	
	Beat perception % correct & confident	.282	
	Beat perception rating correct answers	.313	
	Beat perception rating incorrect answers	-.085	
Sense of rhythm	Paced abs. mean diff. 90 bpm	-.259	
	Paced abs. mean diff. 120 bpm	-.429	
	Paced mean abs. error freq. 90 bpm	.081	
	Paced mean abs. error freq. 120 bpm	-.691	.003

	Paced mean variability 90 bpm	-.549	.028
	Paced mean variability 120 bpm	.094	
	Unpaced abs. mean diff. 90 bpm	.019	
	Unpaced abs. mean diff. 120 bpm	-.479	
	Unpaced mean abs. error freq. 90 bpm	.131	
	Unpaced mean abs. error freq. 120 bpm	-.574	.028
	Unpaced mean variability 90 bpm	-.334	
	Unpaced mean variability 120 bpm	-.365	
	Beat perception % correct	.157	
	Beat perception % correct & confident	.468	
	Beat perception rating correct answers	.479	
	Beat perception rating incorrect answers	.200	
Physical coordination	Paced abs. mean diff. 90 bpm	-.315	
	Paced abs. mean diff. 120 bpm	-.496	
	Paced mean abs. error freq. 90 bpm	-.104	
	Paced mean abs. error freq. 120 bpm	-.344	
	Paced mean variability 90 bpm	-.078	
	Paced mean variability 120 bpm	.127	
	Unpaced abs. mean diff. 90 bpm	-.039	
	Unpaced abs. mean diff. 120 bpm	-.334	
	Unpaced mean abs. error freq. 90 bpm	-.006	
	Unpaced mean abs. error freq. 120 bpm	.027	
	Unpaced mean variability 90 bpm	-.192	
	Unpaced mean variability 120 bpm	-.237	
	Beat perception % correct	-.155	
	Beat perception % correct & confident	.096	
	Beat perception rating correct answers	.130	
	Beat perception rating incorrect answers	.157	
Frequency participating in sports	Paced abs. mean diff. 90 bpm	.129	
	Paced abs. mean diff. 120 bpm	.060	
	Paced mean abs. error freq. 90 bpm	.122	
	Paced mean abs. error freq. 120 bpm	.071	
	Paced mean variability 90 bpm	-.072	
	Paced mean variability 120 bpm	.187	
	Unpaced abs. mean diff. 90 bpm	-.370	
	Unpaced abs. mean diff. 120 bpm	-.118	
	Unpaced mean abs. error freq. 90 bpm	-.290	
	Unpaced mean abs. error freq. 120 bpm	-.214	
	Unpaced mean variability 90 bpm	.082	
	Unpaced mean variability 120 bpm	-.033	
	Beat perception % correct	-.087	
	Beat perception % correct & confident	.143	
	Beat perception rating correct answers	-.006	
	Beat perception rating incorrect answers	.250	

7.8.4. Correlation results for training performance with changes in reading, tapping and beat perception performance variables from the pre to post-test

Table 7.4: Results of the correlation analyses of training performance with changes in reading, tapping and beat perception performance variables from the pre to post-test. No *p*-values are reported because there were no significant correlations. Only participants from the training group were included in the analyses.

Variable 1	Variable 2	Correlation	*P*-value
Training performance ranking	Reading accuracy	.518	
	Reading speed	.310	
	Reading comprehension	-.417	
	Paced abs. mean diff. 90 bpm	-.595	
	Paced abs. mean diff. 120 bpm	-.048	
	Paced mean abs. error freq. 90 bpm	-.119	
	Paced mean abs. error freq. 120 bpm	.690	
	Paced mean variability 90 bpm	.190	
	Paced mean variability 120 bpm	.190	
	Unpaced abs. mean diff. 90 bpm	-.405	
	Unpaced abs. mean diff. 120 bpm	-.429	
	Unpaced mean abs. error freq. 90 bpm	-.548	
	Unpaced mean abs. error freq. 120 bpm	.333	
	Unpaced mean variability 90 bpm	.072	
	Unpaced mean variability 120 bpm	.048	
	Beat perception % correct	-.254	
	Beat perception % correct & confident	-.578	
	Beat perception rating correct answers	-.452	
	Beat perception rating incorrect answers	-.177	

7.9. Appendix I

7.9.1. Praat analyses

After completion of the pre and post-tests, the assessment of the reading performance recordings prompted the subjective observation by the author that prosodic elements were more evident among more fluent readers. It was therefore determined that these elements were worth attempting to objectively quantify. A scientific speech analysis computer program called Praat (Phonetics Sciences, Amsterdam, praat.org) was therefore used in order to analyze the frequency (pitch; in Hz) and intensity (dynamic; in dB) ranges of each reading performance in the pre and post-tests. It was reasoned that wider ranges of frequency and intensity might reflect a higher degree of prosody.

Both range in frequency and range in intensity variables were analyzed using separate two-way repeated measures ANOVAs, with time (pre-test, post-test) as the within-subjects factor, and group (test, control) as the between subjects factor. The ANOVAs revealed no significant main or interaction effects (all *p*'s > 0.05). The results are presented in Figure 7.1.

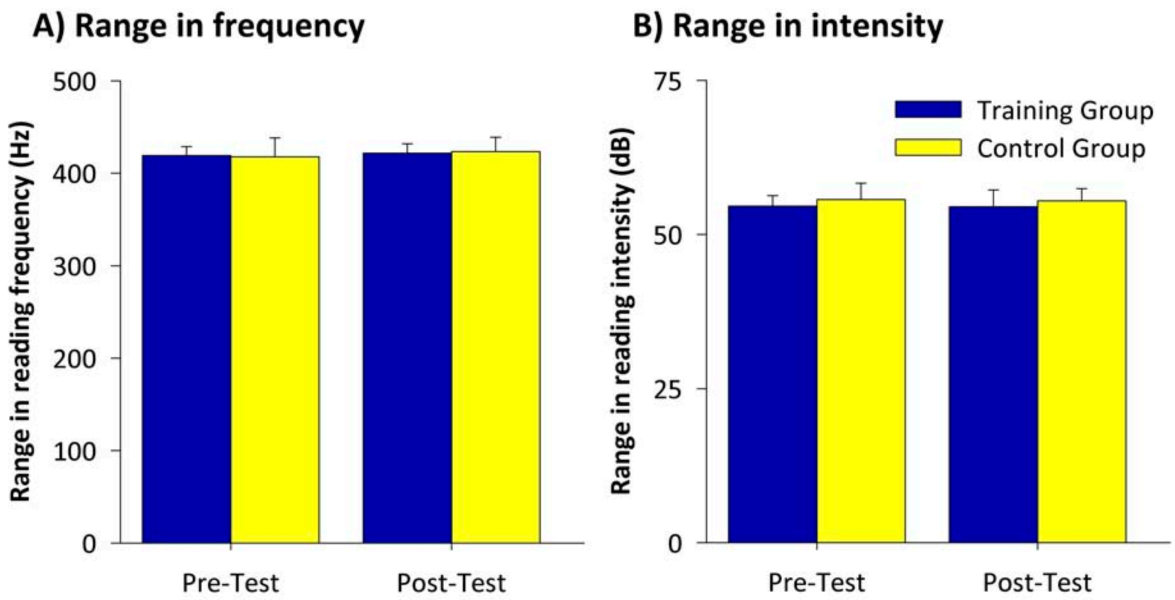

Figure 7.1: Mean range in reading frequency (in Hz; A) and intensity (in dB; B) for the training (blue bars) and control (yellow bars) groups from the reading performance for the pre and post-tests analyzed using Praat. Error bars represent standard deviations.

With the quantification of prosodic elements obtained by the intensity and frequency measurements on Praat, it was possible to objectively correlate prosody with other relevant measurements obtained in this study. Pearson's correlation coefficients were therefore calculated to investigate whether there was a relationship between the range in frequency and range in intensity data obtained from Praat with reading accuracy scores for the pre and post-tests with all participants. However, no significant correlations were found (all *p*'s > 0.05; see Table 7.5). The frequency and intensity data were therefore not subjected to further analyses or included in the main methods and results sections.

Table 7.5: Results of the correlation analyses of reading accuracy with reading frequency range and reading intensity range for both the pre and post-tests. No *p*-values are reported because there were no significant correlations. Participants from the training and control groups are included in the correlations.

		Pre-Test		Post-Test	
Variable 1	**Variable 2**	**Correlation**	***P*-value**	**Correlation**	***P*-value**
Reading accuracy	Reading frequency range	.011		-.445	
	Reading intensity range	-.290		.215	