Do Musical Training and Cognitive Abilities Predict Rhythm Synchronization and Melody Discrimination Performance in Children?

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ABSTRACT

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A sensitive period for musical training has been proposed. Adult musicians who began lessons prior to age 7 have been found to have superior rhythm synchronization and enhancements in brain structures when compared to musicians who started later in life. These differences exist even when early-trained (ET) and late-trained (LT) groups are matched for musical training, formal lessons, and current practice. Moreover, duration of musical training is associated with better performance on measures of rhythm and melody discrimination. Finally, musical training has been shown to directly improve scores on IQ tests and is highly correlated with measures of auditory working memory and nonverbal reasoning skills. The aim of the present study is to investigate whether sensitive-period effects can be observed in childhood. A secondary aim is to investigate the contributions of age-of-start, duration of lessons, and cognitive abilities to performance on musically relevant tasks. Fifty-one children enrolled in music lessons were tested on measures of rhythm synchronization and melody discrimination. Working memory and nonverbal reasoning abilities were also measured. A subsample of 14 children was compared to age-matched controls with no musical training on a measure of rhythm synchronization. No early-training effect was observed in the matched subsample, while older children (regardless of training) performed significantly better on the rhythm synchronization task. In the full sample, duration of musical training and working memory abilities predicted rhythm synchronization performance. By contrast, the interaction of musical training and age of start, but not working memory, predicted melody discrimination performance.

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Acknowledgments

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Do Musical Training and Cognitive Abilities Predict Rhythm Synchronization and Melody Discrimination Performance in Children?

A sensitive period is defined as a developmental window in childhood during which skills training and developmental trajectories interact to produce long-lasting changes in the brain and behaviour (Bailey & Penhune, 2013). During a sensitive period, the effects of specific experience are more pronounced than during other periods in development (Knudsen, 2004). Evidence for a sensitive period is based in anatomical studies that found enhancements in brain structure in adult musicians who began training prior to age seven (Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995). These results are supported by findings from our laboratory that early-trained (ET) musicians (age of start < 7) showed superior performance on synchronization tasks and enhancements in brain structure when compared to late-trained (LT) musicians (age of start > 7; Bailey & Penhune, 2010, 2012; Watanabe, Savion-Lemieux and Penhune, 2007; Steele, Bailey, Zatorre & Penhune, 2013), and from evidence of enhanced sound processing in the auditory brainstem after musical training in young children (Putkinen, Tervaniemi, Saarikvi, Ojala, & Huotilainen, 2013).

The aim of the present study is to explore whether the early-training advantage found in adult musicians can also be observed in children. Previous controlled studies with children show that musical training can alter brain anatomy and function after one to three years (Hyde, Lerch, Norton, Forgeard, Winner, Evans et al., 2009; Putkinen et al., 2013). Thus, in the current study we compared groups of early- and late-starting children who had a minimum of three consecutive years of training. We used two musical tasks – rhythm synchronization and melody discrimination – that have previously been found to show differences between early and late-trained adult musicians (Bailey & Penhune, 2010, 2012; Foster & Zatorre, 2010a). We also examined the contribution of specific cognitive abilities – auditory working memory and non-verbal reasoning – that have been shown to be positively associated with music training in children (e.g., Forgeard, Winner, Norton, & Schlaug, 2008). We predicted that early-trained music students would outperform late-trained students in comparison to age-matched controls and that greater length of training would result in better performance. Finally, we wanted to examine the relationship between performance on cognitive tasks and performance on musically relevant tasks.

The earliest evidence for a sensitive period for musical training comes from neuroanatomical studies (Schlaug et al., 1995; Amunts, Schlaug, Jäncke, Steinmetz, Schaicher, Dabringhaus et al., 1997). Highly trained adult musicians had a significantly larger anterior corpus callosum than non-musicians, and the difference was greatest for those who had begun musical training prior to age seven. It was hypothesized that morphological differences in the corpus callosum reflected an enhanced inter-hemispheric connectivity due to musicians' intensive bimanual training (i.e., learning to play with both hands independently; Schlaug et al., 1995). Similarly, Amunts et al. (1997) found a significant negative association between age of start of musical training and motor cortex size, as measured by the intrasulcal length of the precentral gyrus, in adult musicians.

Using Schlaug's age cutoff of seven years, researchers in our laboratory have studied behavioural and brain differences between early-trained (ET) and late-trained (LT) musicians. We also incorporated a matching paradigm to ensure that ET-LT differences in task performance were not confounded by years of experience, formal training, or current practice (Watanabe et al., 2007). Four studies have used this matching paradigm with adult participants to study sensitive-period effects.

Watanabe et al. (2007) and Steele et al. (2013) used a timed motor sequence task (TMST), a measure of visual-motor synchronization, in which participants tapped in synchrony with a square that flashed rhythmically on a computer screen. Bailey and Penhune (2010, 2012) used a rhythm synchronization task (RST), a measure of auditory-motor synchronization, in which participants tapped in synchrony with rhythms presented via headphones. In all four studies, ET musicians showed more accurate sensorimotor synchronization than their LT counterparts, while controlling for total musical experience (Watanabe et al., 2007; Bailey & Penhune, 2010, 2012; Steele et al., 2013). Moreover, ET musicians outperformed LT musicians on a melody discrimination task (Bailey, Zatorre, & Penhune, 2014). To validate the ET-LT cutoff age of seven, Bailey and Penhune (2013) computed correlations between rhythm synchronization performance and age of start, using ages six through nine as cutoff ages. The correlation was strongest with an ET cutoff age of seven, as originally suggested by Schlaug and colleagues (1995).

In addition to performing better on rhythm synchronization and melody tasks, early-trained musicians were found to have greater surface area in the right ventral premotor cortex, a region within the auditory-motor network (Bailey et al., 2014). This structural difference was significantly correlated with age of start. Steele and colleagues (2013) measured functional connectivity and plasticity in the corpus callosum of ET and LT musicians, and found that white-matter integrity was greater for ET musicians in the posterior midbody of the corpus callosum. This area connects the left and right sensorimotor cortices, important for synchronization ability, and it undergoes major changes between the ages of six and eight (Westerhausen et al., 2011), supporting a sensitive period for musical training in this region.

Taken together, evidence from behavioural and brain-imaging studies supports a sensitive-period effect for sensorimotor synchronization abilities in adult musicians. Obviously, such an effect is likely the result of an interaction between development, experience, and ongoing practice over several years. However, relatively little is known about how early in development a sensitive-period effect could be observed. To date, a handful of researchers have conducted longitudinal studies of the effects of music lessons on brain structure and function during childhood, but none have examined the effect of the age of start of training.

Hyde and colleagues (2009), in a randomized controlled trial with six-year-old children, found significant increases in volume in motor-related brain areas, including the precentral gyrus and corpus callosum, after 15 months of keyboard lessons. The observed changes in brain structure were correlated with performance on measures of rhythmic and melody discrimination skills, and motor sequencing. Evidence from electrophysiological studies has further highlighted training-induced neuroplasticity in children. Shahin, Roberts, and Trainor (2004) used electroencephalography (EEG) to study evoked responses in primary and secondary auditory cortex in preschool-aged children before and after one year of Suzuki music lessons. They found that responses were higher in musically trained children. Similarly, Fujioka et al. (2005) found heightened responses to violin sounds, but not to noise, in children aged four to six after one year of Suzuki lessons. Children in the Suzuki music group also showed significant improvements in measures of auditory discrimination and working memory. Finally, Putkinen and colleagues (2013) studied children with and without music lessons, every two years from age seven to 13. Children with lessons showed higher amplitude and steeper growth in evoked responses to difficult-to-perceive musical stimuli, a response previously found to distinguish musicians from non-musicians (Fujioka et al., 2004). Of note, differences were not observed between musical and non-musical groups until age 11 (i.e., after four years of musical training).

Taken together, longitudinal studies with children have provided compelling evidence for the benefits of early musical training. Exposure to music lessons in childhood has been found to enhance both the development of brain structure (i.e., greater cortical volume) and function (i.e., improved auditory processing and working memory). Moreover, in some cases these structural and functional changes are associated with meaningful improvements on musically relevant behavioural tasks, a finding echoed in studies with adult musicians.

Previous studies conducted in our lab have not found any differences in cognitive function between ET and LT adult musicians; however, working memory has consistently been associated with rhythm synchronization performance and years of formal training in both musician groups (Bailey & Penhune, 2010, 2012, 2013). Moreover, several researchers have used correlational methods to examine the association between musical training and cognitive abilities in childhood. For instance, school-aged children with an average of four-and-a-half years of lessons were found to outperform their age-matched counterparts with no musical training on measures of vocabulary and nonverbal reasoning (Forgeard et al., 2008). Another group of researchers (Ho, Cheung, & Chan, 2003) found that boys with an average of two-and-a-half years of training scored higher on immediate and delayed verbal working memory (a word-list recall task). More recently, Nutley, Darki, & Klingberg (2013) followed children and young adults aged 6-25 for six years, and found that those in the musically-trained group had higher scores on measures of verbal working memory (a digit-span task) and nonverbal reasoning (a matrix-completion task). The authors also found a dose-response relationship between weekly music practice and improvements in verbal working memory over one year. An experimental study provides more direct evidence for the cognitive benefits of music lessons. Schellenberg (2004) measured full-scale IQ in 144 children randomly assigned to keyboard lessons, singing lessons, drama lessons, or no lessons. The two music groups (keyboard and vocal) had a statistically larger increase in IQ after one year than the two control groups (drama and no lessons).

In sum, the primary objective of the present study is to understand whether sensitive-period effects previously found in early-trained adult musicians – that is, superior performance on rhythm synchronization – can be observed in children. The traditional paradigm used in our lab for testing sensitive-period effects requires a direct comparison of ET and LT musicians that are matched for years of training. However, consistent with general maturational trends we can expect that older children will perform better (Gerber, Wilks, & Erdie-Lalena, 2010). A simple ET-LT comparison provides no useful information about the impact of early training. Thus, the ET and LT children in this study are compared to age-matched control participants with no musical training. If sensitive-period effects can indeed be observed in childhood, we expect ET children to show greater performance differences relative to age-matched controls compared to LT children.

A second, broader goal is to elucidate the relationship between early musical training, cognitive abilities, and performance on rhythm synchronization and melody discrimination tasks. Similar to previous findings, we predict that early onset and years of lessons will be significant predictors of performance. Finally, we hypothesize that working memory and nonverbal reasoning abilities will significantly contribute to performance.

Method

Participants

Fifty-one school-aged children (*M* = 10.72 years old; *SD* = 1.78) were recruited from Suzuki Institute music camps and private music lessons in Montréal and Waterloo, Canada (Table 1). All children played piano or strings (piano = 13; violin = 32; cello = 5; and viola = 1), and were currently enrolled in weekly one-on-one music lessons (mean weekly playing time = 3.89 hours, *SD* = 2.80). Age-of-start of musical training ranged from three to 8.5 years (*M* = 5.04 years, *SD* = 1.40), and all children had at least three years of consecutive music lessons (*M* = 5.68 years, *SD* = 1.61). All spoke either French or English. Parents provided written consent for their children to participate, and children provided verbal assent prior to the testing session. The research protocol was approved by the Concordia University Human Research Ethics Committee.

Tasks and Procedure

Rhythm synchronization task (RST). A computer-based rhythm synchronization task was used to assess children's ability to tap in synchrony with a series of musical rhythms that varied in complexity. Each trial has two phases: listen and listen + tap. First, participants listen to the rhythm, then listen a second time and attempt to tap in synchrony on a single key of the computer mouse (Fig. 1). This task was developed for adults (Chen, Penhune, & Zatorre, 2008) and has recently been adapted for use with children (Hyde et al., 2009). In the child protocol, a giraffe with headphones (Fig. 2) is displayed on the computer screen to cue them when to listen (headphones light up) or tap (the foot lights up).

There are six rhythms, each consisting of 11 woodblock notes spanning a six-second interval. To account for differences in age and musical training, three levels of increasing difficulty were created with two rhythms per level: Easy (E), Metric Simple (MS), and Metric Complex (MC). Rhythms with a strong sense of beat and repeating patterns were classified as Easy, those with a strong beat but no repetition as Metric Simple and those with a syncopated beat were classified as Metric Complex. Each rhythm was presented three times in a counterbalanced order, for a total of 18 trials. Participants were familiarized with the task through five practice trials with feedback from the experimenter.

Performance on the RST is measured by inter-tap interval (ITI) deviation, which measures the ability to reproduce the temporal structure of a rhythm (Chen et al., 2008). As a first step in the analysis, the timing of all taps made by the participant is aligned with the stimulus timing. Only the taps that fall in a window of half the interval around each stimulus are kept to calculate the ITI deviation. If two or more taps are identified, the one that is closest to the stimulus is used. The ITI deviation is calculated as an absolute value by dividing the interval between each pair of the participant's taps by the actual interval between the corresponding pair of woodblock notes in the rhythm subtracted from one (Fig. 3). Lower ITI deviation indicates better performance. This measure has been found to be sensitive in detecting differences between ET and LT musicians (Bailey & Penhune, 2010, 2012).

Melody discrimination task (MDT). A computer-based task was created to assess children's ability to discriminate melodies that differed by a single note. On each trial, participants listen to two melodies of equal duration and indicate whether the second sequence is the same or different (Fig. 4). To account for differences in age and musical training, melodies varied in length from 5-11 notes from the Western major scale, with each note being 320 ms in duration. In developing the child-friendly version of the task, 30 melodies were selected from the original 91, maintaining the original distribution of notes per melody. The task includes two blocks of 15 trials for a total of 30 trials. In 16 of the 30 trials (the "different" trials), the pitch of a single note anywhere in the melody was shifted up or down by up to five semitones. The key and contour (overall pattern of upward and downward movement) of the original melody were maintained despite the shift in pitch.

This measure was adapted for children specifically for this study. Children were cued using a storyline in which a "teacher" elephant 'sang' the first melody. Then the melody was sung back by either the "echoing elephant" ('same') or the "forgetful monkey" ('different'). Children responded on a computer mouse with a sticker representing the small elephant for 'same' and a sticker representing the small monkey for 'different' (Fig. 5). Participants were familiarized with the task through four practice trials: two with feedback from the experimenter, and two without feedback. After every trial, the computer screen displayed immediate feedback with the word 'correct' or 'incorrect.'

Performance on the MDT was measured in terms of proportion of correct responses. Each response was scored as either 0 (incorrect), or 1(correct), and the total of correct responses was divided by the total number of melodies in that block. Scores closer to 1 indicate better performance.

Cognitive tasks. Cognitive abilities were measured with the Digit Span, Letter-Number Sequencing, and Matrix Reasoning subtests from the Wechsler Intelligence Scale for Children, fourth edition (WISC-IV; Wechsler, 2003). For Digit Span (DS), the individual must repeat increasingly long strings of digits forward and backward. For Letter-Number Sequencing (LNS), the individual hears a string of letters and numbers and must repeat them back in numerical and alphabetical order, respectively. Although both subtests measure auditory working memory, Letter-Number imposes a heavier cognitive load due to the additional sequencing demand. For Matrix Reasoning (MR), the individual must identify the missing portion of an incomplete visual matrix from one of five response options. This task measures non-verbal reasoning and visual pattern recognition.

These three subtests were chosen based on Schellenberg's (2006) findings that working memory and non-verbal reasoning are the most common intelligence measures associated with musical training. These subtests have been found to have high test-retest reliability and internal consistency (DS, 32 day test-retest r_{12} = .81, split half r_{xx} = .87; LN, 32 day test-retest r_{12} = .75, split half r_{xx} = .90; MT, 32 day test-retest r_{12} = .77, split half r_{xx} = .89; Wechsler, 2003). All subtests were administered according to standardized procedures. Participants' raw scores were converted to scaled scores based on age-based norms for all three subtests. Further, Digit Span and Letter-Number Sequencing scaled scores were added to produce a Working Memory Index (WMI) scaled score. The population-based mean for subtest scaled scores on the WISC-IV is 10, with a standard deviation of 3 (Wechsler, 2003).

Survey of Musical Interests. Participant demographics and history of musical experience were measured with the Survey of Musical Interests (SMI), a questionnaire developed by Desrochers, Comeau, Jardaneh, & Green-Demers (2006) for use in the Piano Pedagogy Research Laboratory at the University of Ottawa, Canada. This questionnaire provides information about the age at which the child began musical training (i.e., age of start), months of consecutive music lessons since age of start, and hours of current weekly practice.

General procedure. Testing took place either over a 1.5-hour session at Concordia University or over two, 45-minute sessions in Suzuki music camps. All participants were given two- to five-minute breaks between tasks. Auditory-motor tasks (RST, MDT) were administered on a laptop computer running Presentation software (Neurobehavioral Systems, http://www.neurobs.com/). Computer-based task order was randomized across participants.

Tasks were cued by a visual display presented on a computer monitor. After participants were familiarized with each task, auditory stimuli were presented binaurally via Sony MDRZX100B headphones adjusted to a comfortable sound level. Cognitive tasks (Digit Span, Letter-Number Sequencing, Matrix Reasoning) were administered in the order in which they appear in the original assessment battery. The Survey of Musical Interest was administered after computer-based and cognitive tasks. Parents filled out one questionnaire per participating child concurrent to the testing session.

Analysis

To address sensitive-period effects, performance on the RST within the age-matched ET-LT sample was analyzed with a between-subjects 2 × 2 analysis of variance (ANOVA). The two factors were age group (ET and LT) and musical training (music students and age-matched controls), and the dependent variable was ITI deviation. Effect sizes were derived using omega squared.

To address the contributions of early musical training and cognitive abilities on performance on the RST and MDT, two separate multiple regression analyses were carried out with the full music student sample ($N = 51$). The independent variables (predictors) were age of start ('onset'; in months), lessons (in months), an interaction term to control for intercorrelation (onset-by-lessons), and scaled scores on the Working Memory Index and Matrix Reasoning subtest. The dependent variables were ITI deviation and proportion correct for the rhythm and melody tasks, respectively. Shrinkage-corrected squared multiple-correlation (adjusted R-squared) effect sizes are reported for both models.

Results

Matching Process

Music students (*N* = 51) were classified as Early-Trained or Late-Trained (ET or LT) according to previous sensitive-period studies with adults (Watanabe et al., 2007; Bailey & Penhune 2010, 2012). Those who started lessons before age seven were categorized as ET, and those who started after age seven as LT. After categorization, forty-four children were in the ET group (mean age of start = 4.63 years, *SD* = 1.06), and seven in the LT group (mean age of start = 7.64, *SD* = .50). The seven LT children were then individually matched to seven ET students based on years of training (ET, *M* = 5.78 years, *SD* = 1.61; LT, *M* = 5.02, *SD* = 1.25). This last step follows the matching paradigm previously developed in our lab. The resulting ET and LT groups (*N* = 14) did not differ in years of training (*t* [12] = .02, *p* = .99).

Our collaborator, Dr Krista Hyde (Université de Montréal), provided data for the control participants on the Rhythm Synchronization Task (*N* = 14; Table 2). These non-music students were individually matched with ET and LT students based on current age (ET-Control, *M* = 9.07 years, *SD* = 1.01; LT-Control, *M* = 12.83, *SD* = 1.26). The age-matched control subjects did not differ significantly in age from their respective ET and LT counterparts (ET-Control, *t* [12] = .28, *p* = .78; LT-Control, *t* [12] = -.25, *p* = .81).

Matched Sample (ET & LT vs Controls): Rhythm Synchronization

A 2-by-2 ANOVA was conducted to test the hypothesis that ET music students would outperform their LT counterparts relative to age-matched controls on the RST. As predicted, there was a statistically significant main effect of age ($p < .01$, $\varpi^2 = .44$): older children (LT and LT-Controls) outperformed younger children (ET and ET-Controls). There was no main effect of musical training ($p > .05$, $\varpi^2 = .02$), and no interaction between age of onset and musical training ($p > .05$, = .01). The difference between ET-MS and ET-NMS was not greater than the difference between LT-MS and LT-NMS.

Full Sample: Rhythm Synchronization and Melody Discrimination

Two separate multiple regressions were conducted to examine the contribution of musical training and cognitive abilities to performance on the rhythm and melody tasks. A particularity of this sample is that the variable ‘age’ is equal to the sum of ‘age of onset’ and ‘lessons.’ Thus, to control for multicollinearity age was left out of the regression equations (Kline, 2009). In addition to age of onset and lessons, their product ('onset-by-lessons') was computed and entered in both regression models to control for and test the interaction of its two component predictors. Finally, scaled scores from the Working Memory Index and Matrix Reasoning subtest were added to the equation. Intercorrelation and regression tables for all variables of interest are shown in Appendix C.

For rhythm performance, the regression model with age of onset, months of lessons, onset-by-lessons interaction, working memory, and matrix reasoning as predictors explains 38% of the variance in ITI deviation ($p < 0.001$; Table C2). Older age of onset contributed significantly to the model ($\beta = -1.059$, $p = 0.021$), as did more lessons ($\beta = -1.059$, $p = 0.021$). Higher working memory was also a significant predictor of ITI deviation scores ($\beta = -.364$, $p = 0.004$). The onset-by-lessons interaction ($\beta = .610$, $p = 0.241$) and matrix reasoning scores ($\beta = -.018$, $p = 0.889$) were not statistically significant predictors and are thus not interpreted here.

For melody performance, the computer program did not record scores from two participants; data for the remaining 49 children are included in the analysis. The regression model with age of onset, lessons, onset-by-lessons, working memory and matrix reasoning explains 13.5% of the variance in proportion correct ($p = .048$, Table C3). Younger age of onset ($\beta = -1.351$, $p = 0.014$) and fewer lessons contributed significantly to the model ($\beta = -1.160$, $p = 0.036$). The onset-by-lessons interaction was a significant predictor of melody performance ($\beta = 1.272$, $p = 0.047$). Children who started earlier showed superior performance on the MDT, regardless of duration of lessons. However, in children who had started later, more lessons were strongly associated with better performance, and fewer lessons with worse performance. (To illustrate this interaction, the continuous predictors onset and lessons were dichotomized using a median split; Fig. 6). Higher working memory was not a significant contributor to the melody task ($\beta = 0.165$, $p = 0.263$). Finally, as in our rhythm task, matrix reasoning ($\beta = -.136$, $p = 0.399$) was not a statistically significant predictor and is not interpreted.

Discussion

Matched Sample Comparison

The primary objective of this study was to examine whether early-trained (ET) children would outperform late-trained (LT) children on a rhythm synchronization task (RST). To this end, we compared ET and LT music students, matched for duration of training, to non-music students matched for age. Our hypothesis of a sensitive-period effect for early musical training on rhythm synchronization abilities was not supported. Irrespective of whether they took music lessons, older children performed best on the Rhythm Synchronization Task (RST). To our knowledge, no studies have been published to date with the RST in children. However, the task is part of an ongoing multi-site study comparing typically developing (TD) children to those with Autism Spectrum Disorder. Preliminary data from the Montréal site show that, similar to our findings, older TD children perform better on the child version of the RST (Tryfon, 2014, personal communication).

The most obvious explanation for the main effect of age is that older children have more highly developed auditory-motor integration abilities, and thus better synchronization. This assumption has a theoretical basis in Dynamic Attending Theory, which posits that attunement (i.e., synchronization) to rhythms is a function of neural oscillations, which are more loosely connected to real-time events in children than adults (Drake, Jones, & Baruch, 2000). Indeed, many researchers have found evidence for progressive improvement in rhythm synchronization abilities from childhood to adulthood. Drewing, Aschersleben and Li (2006) showed that, within a large sample aged 6-88 years, the ability to synchronize taps with a metronome improved consistently until approximately age 15 and remained relatively stable thereafter. Savion-Lemieux, Bailey and Penhune (2009) compared 6-, 8-, and 10-year-olds to adults on a task where they learned to synchronize their taps on a four-key pad with visually presented rhythms. After two days of trials, the 10-year-olds performed similarly to adults, but the 6- and 8-year olds' performance had failed to improve. Another group found that children's finger-tapping speed increased with age, and correlated positively with corticospinal (i.e., neuro-motor) maturation (Garvey, Ziemann, Bartkoa, Dencklac, Barkera & Wassermann; 2003). Similarly, De Guio, Jacobson, Molteno, Jacobson, and Meintjes (2012) showed that children aged 10-13 performed at the level of adults on a finger-tapping synchronization task, but that adults recruited fewer brain regions while tapping. Together, these results suggest a developmental progression (in behaviour and in the brain) toward efficiency in sensorimotor synchronization.

A methodological limitation must be considered in our interpretation of the ET-LT comparison, in that it rests on a very small sample (14 musicians and 14 controls). Many researchers have reported enhanced synchronization skills in ET compared to LT musicians (Bailey & Penhune, 2010, 2012; Steele et al., 2013; Watanabe et al., 2007). It is likely that our sub-sample of ET and LT children and controls lacked adequate power to detect an effect of early training. Data for this study were collected in the first stage of an ongoing project, with a second round of recruitment and testing currently underway. Having a larger sample of later-trained music students and control subjects for both the rhythm and melody tasks will allow us to draw more meaningful comparisons about sensitive periods for musical training in children.

Full Sample Regressions

A secondary objective of our study was to investigate the contributions of five variables to rhythm and melody performance: (1) age of onset, (2) duration of musical training, (3) the interaction of onset and lessons, (4) working memory, and (5) matrix reasoning. First, we found that younger age of onset did not emerge as a strong predictor of rhythm synchronization performance. This is congruent with our smaller matched sample (where we did not find an early-onset effect for rhythm synchronization). However, the result is at odds with previous sensitive-period research in our lab using the adult version of the RST. Bailey and Penhune (2010, 2012) found that ET musicians were better able to synchronize their taps to a rhythm than LT musicians, even when matched for lifetime duration of musical training. Consistent with our prediction, and with sensitive-period research in general, younger age of onset significantly predicted melody performance. This result is similar to a study using the MDT with adults, which showed a younger age of onset to be correlated with melody discrimination abilities (Foster & Zatorre, 2010a).

Our mixed results with age of onset as a predictor may also reflect a methodological issue, in that we used a convenience sample with students enrolled in Suzuki music lessons. The Suzuki teaching method places central importance on starting lessons early in life (Suzuki, 1969). Consequently, a large majority (44 out of 51) of students in our sample are early-trained (i.e., they started prior to age 7). Our second phase of data collection targeting late-trained (LT) children is currently underway. With a larger LT sample we should be able to observe any effects related to age of start more consistently across tasks.

Next, we found that duration of musical training was a strong predictor of children's performance on the RST, but not on the MDT. This mixed result is puzzling: more music lessons should be associated with better musical skills, including melody discrimination (Schellenberg, 2006). This assumption is central to theories of music cognition which postulate that musical training enhances pitch perception, a consequence of which is the ability to discriminate between differing tones (Dowling & Harwood, 1986). Several researchers have found associations between duration of musical training and performance on the same or similar tasks of rhythm and melody abilities as in our study. For example, Bailey and Penhune (2010, 2012, 2013) showed that performance on the RST correlated significantly with years of lessons in three separate studies with adult professional musicians. Similarly, Foster and Zatorre (2010a) found a significant positive correlation between months of lifetime musical practice and performance on the adult version of the MDT. In a study of 8- to 12-year-old children, training duration significantly correlated with performance on tasks of melody discrimination and motor-sequence learning (Forgeard et al., 2008). Moreover, 9- to 11-year-olds with an average of four years of instrumental training showed a significant advantage on the tonal (i.e., melody discrimination) component of a standardized musical aptitude battery when compared to age-, IQ-, and SES-matched non-musician children (Schlaug, Norton, Overy, & Winner, 2005). It is possible that a minimum duration of musical training is required to observe the predictive effect of lessons on MDT, and that in our sample the duration of lessons (M = 5.68 years) was simply not sufficient.

Notably, we found an onset-by-lessons interaction for the melody task, such that age of onset moderated the impact of lessons on performance. Specifically, children who had an earlier start performed well even with fewer lessons. The impact of lessons became more important as age of onset increased, so that children who had started when they were older performed better with more lessons. This finding is consistent with an early-training (i.e., sensitive-period) effect. Since the melody task was adapted for children specifically for this study, we unfortunately have no other studies for comparison. In the adult version of the task, published in two studies to our knowledge, interactions between age and lessons were not reported (Foster & Zatorre, 2010a, 2010b). Once we have completed data collection with additional LT children we will assess whether this interaction is maintained.

Taken together, our results and previous research suggest that the impact of early training on rhythm and melody skills may be most reliably observed in adult musicians – whose auditory-motor ability is less variable than children's – who have had both an early start to lessons and extensive musical training. Future research should seek to elucidate the age at which the benefits of early training on rhythm and melody performance can reliably be observed; however, to do so a much larger sample is needed. As the sample size increases, we should be able to show with more certainty whether earlier onset predicts performance independent of age. However, if we still do not observe an effect of age of onset in a larger sample, we might then choose to study older adolescents (e.g., aged 16-19), in whom ET and LT groups are more likely to have equivalent motor skill development. We could also specify a longer training duration (e.g., a minimum of 10 years) for inclusion in both ET and LT groups. This might more closely approximate the musical experience of adults in previous sensitive-period research (e.g., Bailey & Penhune, 2010, 2012, 2014). This would facilitate the matching paradigm created in our lab, making it more likely that groups differ only in age-of-start (as opposed to age, formal training experience or musical ability). In such a rigorous comparison we might expect the age-related effects on performance to be diminished and the effects of early training to be more salient.

Finally, in terms of cognitive abilities, we found working memory to be a significant predictor of performance on the rhythm task, but not the melody task. Three studies conducted in our lab have also revealed significant associations between RST performance and scores on the Digit Span and Letter-Number Sequencing (i.e., working memory) subtests in adult musicians (Bailey & Penhune, 2010, 2012, 2013). In previous published studies using the adult version of the MDT task, cognitive measures were not administered. However, our results speak to the broader question of whether musical training improves cognitive abilities overall, including working memory. Several researchers have used correlational methods to investigate this question in both adults and children. For instance, Wallentin et al. (2010) found that professional musicians significantly outperformed non-musicians on a digit-span task. They concluded that working memory and musical skill are inextricably linked since learning to play music requires active retention and manipulation of complex melody and rhythm components. Franklin and colleagues (2008) found that adult musicians had higher recall of word lists than non-musicians, which they attributed to musicians' enhanced verbal rehearsal abilities. Lee and colleagues (2007) tested digit-span abilities in children with an average of six years of musical training. The researchers found main effects of both age (older children had better digit span) and of musicianship (musically trained children had better digit span), but no interaction between the two. Thus, the effect of musical training was independent of age-related increases in memory. Experimental evidence also points to music-related increases in cognitive ability as measured by IQ scores. By randomly assigning 144 children to music lessons, Schellenberg (2004) concluded that music lessons actually increased IQ in school-aged children.

It is important to consider alternate explanations for why musicians have been found to have better working memory. For instance, perhaps children with superior cognitive functioning due to pre-existing (i.e., genetic) differences are more likely to take music lessons, to do better, and thus to pursue training for longer (Schellenberg & Weiss, 2013). Moreover, the relationship between cognitive abilities and performance on musical tasks could be moderated by other variables that are known to influence participation in music lessons and musical skill, such as parents' socioeconomic status (Anderson, Funk, Elliott, & Smith, 2003), parental support for lessons (Creech, 2010), and children's own motivation to pursue music lessons (Comeau, Huta, Liu, & Smith, in submission; Schmidt, 2005). These variables need to be assessed in future studies to investigate whether they have a moderating effect on children's ability to start earlier and/or persist longer in music lessons.

In conclusion, the findings from our sensitive-period investigation with children were inconsistent with findings in adult musicians. Early-trained children did not outperform their late-trained counterparts. Instead, consistent with developmental trajectories of musical skill, older children performed best on the rhythm synchronization task. Given the current problems with sampling, it is necessary to replicate this ET-LT comparison with a larger and more balanced group of children enrolled in music lessons. Our analysis of the full sample revealed that duration of musical training and working memory, but not age of onset, contributed to rhythmic abilities. Conversely, age of onset, but not training duration or working memory, predicted melody discrimination ability. Of note, we found an interaction of age of onset and musical training such that having an earlier start reduced the impact of lessons on performance.

Many researchers have shown experimentally that even small amounts of training at a young age are sufficient to promote enhancements in children's brain structures, auditory processing abilities, and musical skills. Moreover, similar age-of-start effects have been observed in other types of skills training. For instance, researchers found that early bilinguals (i.e., who used both languages daily starting before age 10) outperformed late bilinguals on a task of executive control, and duration of bilingualism was positively related to performance (Lug, De Sa, & Bialystok, 2011). Importantly, however, many sensitive-period studies do not address how or when such immediate benefits transfer to long-term advantages in musical ability. Our study represents an initial exploration of a promising area of research, one that could best be addressed by a longitudinal study. Such a design could elucidate a direct causal link between an early start in music lessons and performance on musical tasks. Moreover, known contributors such as intellectual ability, socioeconomic status, parental support, and children's motivation could be assessed and followed over time. Following children for several years would provide a better understanding of the trajectory of age-of-onset effects, such as the onset-by-lessons interaction observed in our study. Finally, we recommend adding electrophysiological measures such as those in Putkinen et al.'s (2013) longitudinal study to monitor training-related changes in auditory processing concurrent to performance on cognitive and musical measures.

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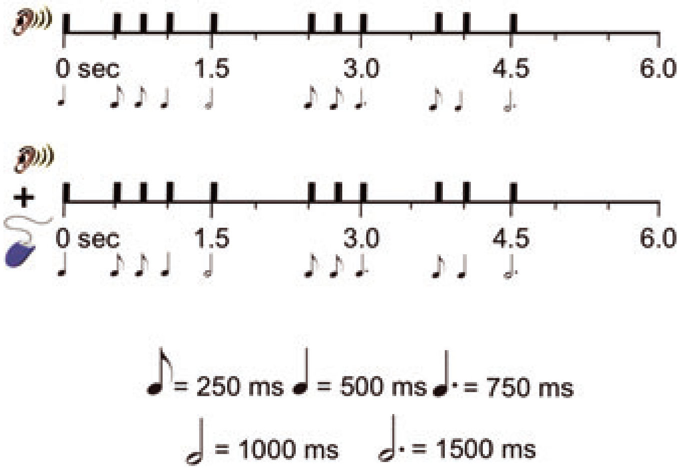
Figure 1. Illustration of the Rhythm Synchronization Task

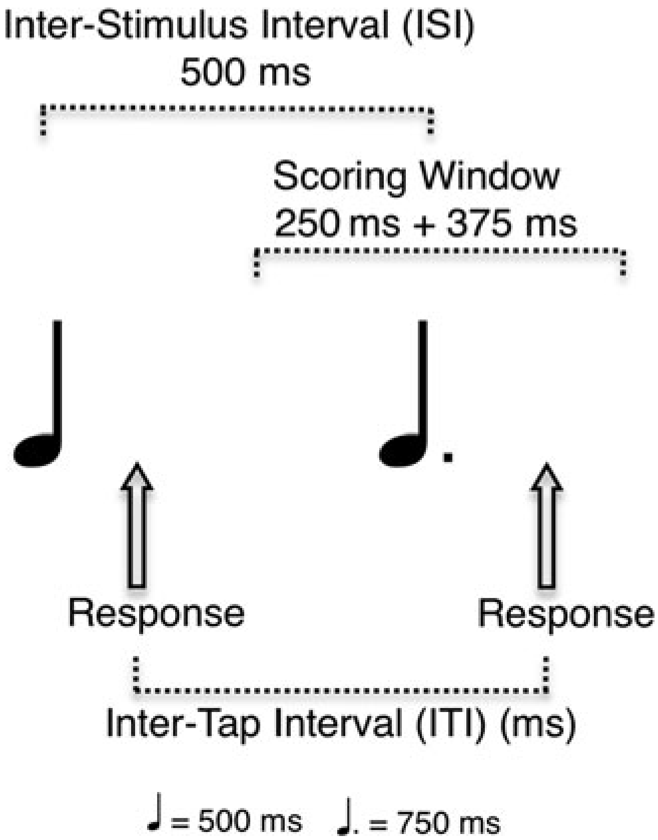


Note. Top sequence = ‘listen’ phase. Bottom sequence = ‘listen + tap’ phase.

Figure 2. Illustration of the visual display for Rhythm Synchronization Task

Note. Image presented in full colour during testing. Giraffe's headphones 'light up' during listen phase; hoof 'lights up' during listen + tap phase.

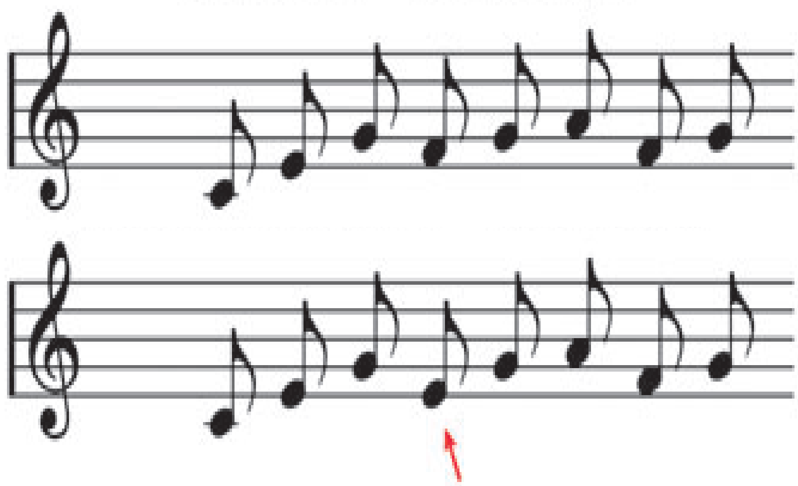
Figure 3. Illustration of scoring method for Rhythm Synchronization Task



Note. Participant's tap is scored if it falls within [(d_1/2) + (d_2/2)] ms of the duration (d) of any two concurrent notes (here, (500 ms/2) + (750 ms/2) = 250 + 375 ms].

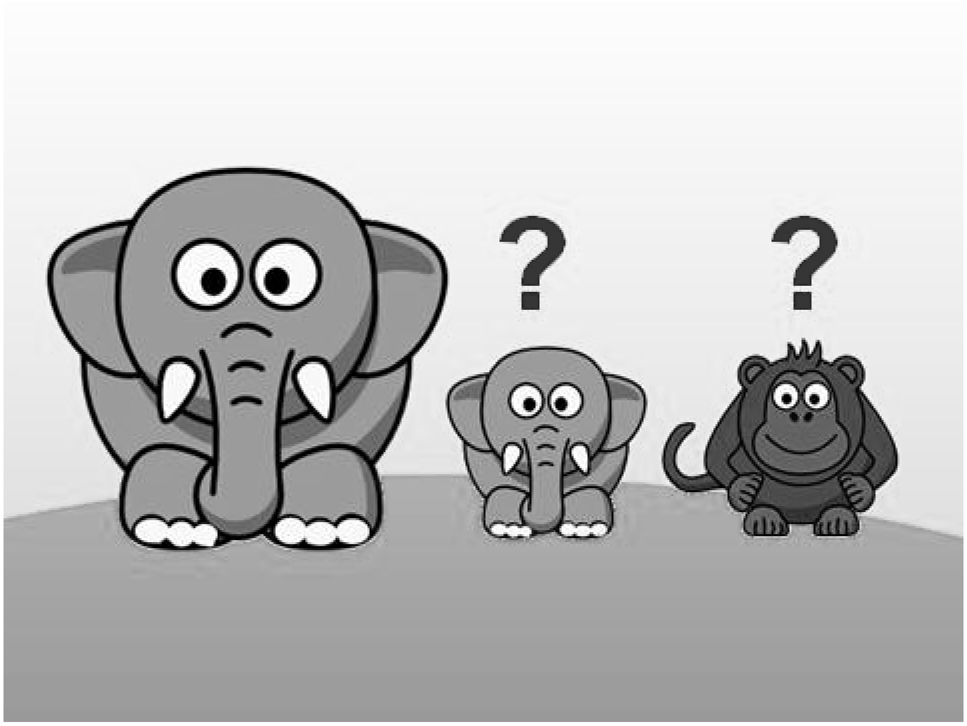
Note. ITI deviation = 1- $\left(\frac{\text{ITI}}{\text{ISI}}\right)$.

Figure 4. Illustration of the Melody Discrimination Task (‘Different’ Trial)



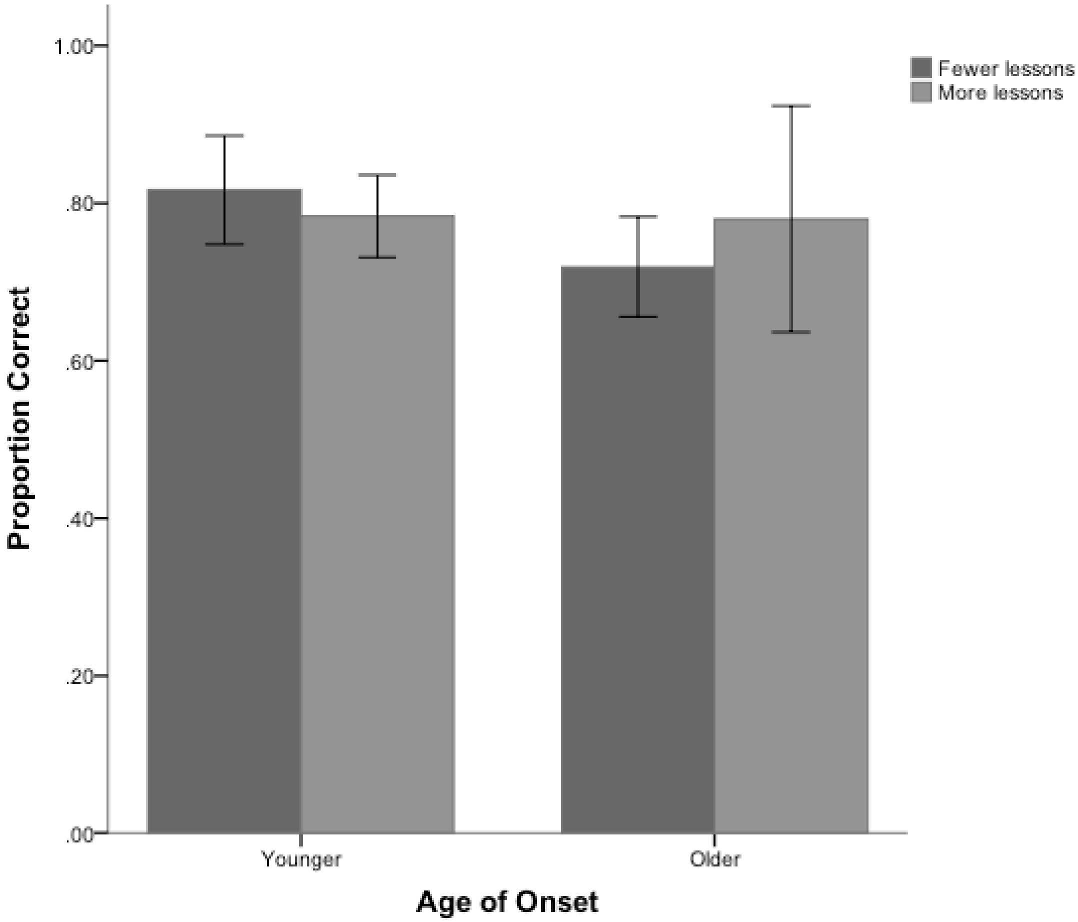
Note. Top sequence = Melody 1 (plays first). Bottom sequence = Melody 2 (plays second). The fourth note differs by one semitone.

Figure 5. Illustration of the visual response probe for Melody Discrimination Task



Note. Image presented in full colour during testing. Participants responded by clicking on a mouse with a sticker identical to the small elephant ('same') or the small monkey ('different').

Figure 6. Interaction of Onset and Lessons in Predicting Melody Scores



Note. Error bars represent a 95% confidence interval.

Table 1

Descriptive Statistics for all Continuous Variables of Interest (Full Sample)

	M (SD)	Range	Skew	Kurtosis
Age at testing (months)	128.67 (21.41)	80.00	.17	-.88
Music lessons (months)	68.14 (19.26)	79.00	.14	-.54
Age of onset (months)	60.53 (16.81)	66.00	.74	-.28
ITI deviation[a]	.32 (.07)	.28	.85	-.01
Proportion correct[b]	.78 (.11)	.42	-.26	-.40
Working Memory Index (scaled score)	23.16 (4.31)	19.00	.58	.32
Matrix Reasoning (scaled score)	11.90 (2.62)	11.00	.47	-.10

Note. [a]$N = 51$. [b]$N = 49$. Values are rounded up two decimal places.

Table 2

Descriptive Statistics For All Continuous Variables of Interest by Group (Age-matched Sample)

	Group			
	ET (*n* = 7)	ET-Control (*n* = 7)	LT (*n* = 7)	LT-Control (*n* = 7)
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Age at testing (months)	110.57 (10.50)	108.86 (12.08)	151.86 (17.26)	154.00 (15.15)
Music lessons (months)	59.43 (14.03)	--	56.14 (13.70)	--
Age of onset (months)	55.57 (12.69)	--	91.71 (6.02)	--
ITI deviation	.36 (.07)	.35 (.05)	.27 (.02)	.28 (.03)

Note. *N* = 28. Values are rounded up two decimal places.

Appendix A: Cell Means and Standard Deviations

Table A

Cell Means, Standard Deviations, and Sizes for ITI Deviation (Age-matched Sample).

		Musical Training		
Age Group	*n*	Music Student	Age-matched Control	Row means
Early-trained	14	.36 (.07)[a] 7[b]	.35 (.05) 7	.35 (.06)
Late-trained	14	.27 (.02) 7	.28 (.03) 7	.27 (.02)
Column means		.31 (.07)	.31 (.05)	

[a]Cell mean (standard deviation). [b]Cell size.

Appendix B: ANOVA Source Table

Table B

2x2 Analysis of Variance Results: ITI Deviation (Age-matched Sample)

Source	*SS*	*df*	*MS*	*F*	*p*	ϖ^2
Age group	.046	1	.046	22.253	.000	.44
Musical training	.000	1	.000	.007	.935	.02
Age group x musical Training	.001	1	.001	.555	.464	.01
Within (error)	.050	24	.002			
Total	.098	27				

Note. $N = 28$.

Appendix C: Multiple Regression Tables

Table C1

Summary of Zero-order Correlations, Means and Standard Deviations for Demographic, Rhythm and Melody, and Cognitive Variables

Measure	1	2	3	4	5	6	7	*M*	*SD*
1. Age (months)	1.00	-.514**	.663**	-.533**	-.191	-.254	-.258	128.67	21.41
2. Age of onset (months)		1.00	-.302*	-.241	-.303*	-.349*	-.403**	60.53	16.81
3. Lessons (months)			1.00	-.382**	.044	.022	.065	68.14	19.26
4. ITI deviation				1.00	.060	-.200	-.012	.32	.07
5. Proportion correct					1.00	.224	.044	.78	.11
6. Working Memory						1.00	.433**	23.16	4.31
7. Matrix Reasoning							1.00	11.90	2.62

Note. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table C2

Multiple Regression Results: Rhythm Synchronization Task (ITI Deviation)

Variable	b	SE_b	*β*	*t*	*P*
(Constant)	.848	.127		6.679	.000
Age of onset	-.004	.002	-1.059	-2.395	.021
Lessons	-.004	.002	-1.059	-2.402	.021
Age of onset x Lessons	< .001	.000	.610	1.189	.241
Working Memory Index	-.006	.002	-.364	-3.033	.004
Matrix Reasoning	.000	.003	-.018	-.141	.889

Note. $N = 51$. Full model adjusted $R^2 = .38$, $p < .001$.

Table C3

Multiple Regression Results: Melody Discrimination Task (Proportion Correct)

Variable	b	SE_b	*β*	*t*	*P*
(Constant)	1.261	.236		5.337	.000
Age of onset	-.009	.003	-1.351	-2.574	.014
Lessons	-.007	.003	-1.160	-2.165	.036
Age of onset x Lessons	.000	.000	1.272	2.047	.047
Working Memory Index	.004	.004	.165	1.135	.263
Matrix Reasoning	-.006	.007	-.136	-.852	.399

Note. $N = 49$. Full model adjusted $R^2 = .135$, $p = .048$.

Appendix D: Consent Form

CONSENT TO PARTICIPATE IN
"DOES STARTING MUSIC LESSONS EARLY PROMOTE SUCCESS FOR CHILDREN?"

I understand that I have been asked to participate in a research project being conducted by Dr. Virginia Penhune (514-848-2424, ext. 7535, virginia.penhune@concordia.ca) and Ms. Kierla Ireland, M.A. (514-848-2424, ext. 7567, kierla.ireland@gmail.com) of the Department of Psychology at Concordia University.

A. PURPOSE

I have been informed that this study is part of a research project entitled, "Does Starting Music Lessons Early Promote Success for Children?" I understand that the goal of this study is to learn about factors that support children's development as it relates to music.

B. PROCEDURES

I understand that:

✓ If I consent to participate in the study, I will be asked to fill out a questionnaire regarding my involvement with music lessons, practice, and recitals; other musical activities I do with my child; and my family musical history. The questionnaire will take me approximately 15 minutes to complete.

✓ If I provide written consent, my child must also provide verbal agreement before participating in the study. During testing, my child will be asked to complete two computer-based musical tasks (60 minutes), two memory tasks and a puzzle task (10-15 minutes), and one questionnaire about their interest in music (20 minutes, with assistance as required).

✓ All the child questionnaires and tasks will be administered by a member of Dr. Penhune's research team.

C. RISKS AND BENEFITS

I understand that the risks to me and child for participating in this research are considered minimal. I understand that the potential benefits of participating in this project are that I will help researchers to understand the factors that help support children's development as it relates to music.

D. CONDITIONS OF PARTICIPATION

I understand that:

- ✓ My privacy and research records will be kept confidential to the extent of the law. Authorized members of Dr. Penhune's research team may know my identity, but they will not disclose any information about me, my child, or our participation in this study to anyone. My questionnaires and my child's completed questionnaires and tasks will be kept completely confidential, and shall only be accessible to authorized members of Dr. Penhune's research team.

- ✓ My child does not have to participate in this study, and that even if I agree now, s/he can withdraw at any time. I also know that my child's participation will not affect their music lessons in any way.

- ✓ Data from this study may be published. However, the data obtained from me or my child will be combined with data from other people in the publication. The published results will never include my name, my child's name, or any other information that would in any way personally identify me or my child.

- ✓ If at any time I have questions about the proposed research, I may contact the study's Principal Investigator, Dr. Virginia Penhune of (514-848-2424, ext. 7535, virginia.penhune@concordia.ca; http://www-psychology.concordia.ca/fac/penhune/), or Ms. Kierla Ireland, M.A. (514-848-2424, ext. 7567, kierla.ireland@gmail.com) of the Department of Psychology, Concordia University. If at any time I have questions about my rights as a research participant, I may contact the Research Ethics and Compliance Advisor, Concordia University, 514-848-2424, ext. 7481, ethics@alcor.concordia.ca

I have carefully studied the above and understand this agreement. I freely consent and voluntarily agree to participate in this study.

Name: ____

Child's name: __________________________________

________ I consent to have my child participate in this study.
________ I do not consent to have my child participate in this study.

Please keep my child's name and contact information in your database for future studies:
Yes______ No______

Signature: _____________________________________

Date: __________________

Phone number: ________________

E-mail address: _________________________________

Appendix E: Formulaire de consentement

<u>CONSENTEMENT À PARTICIPER AU PROJET</u>
<u>« EST-CE QUE DÉBUTER DES LEÇONS DE MUSIQUE EN BAS ÂGE CONTRIBUE AU SUCCÈS DES ENFANTS? »</u>

Il est entendu qu'on m'a demandé de participer à un projet de recherche dirigé par la Dre. Virginia Penhune (514-848-2424, poste 7535, virginia.penhune@concordia.ca) et Madame Kierla Ireland, M.A. (514-848-2424, poste 7567, kierla.ireland@gmail.com) du Département de Psychologie de l'Université Concordia.

A. BUT

Il est entendu que cette étude s'inscrit dans le cadre du projet de recherche intitulé « Est-ce que débuter des leçons de musique en bas âge contribue au succès des enfants? » Il a été porté à ma connaissance que le but de cette étude est d'étudier les facteurs qui contribuent à l'apprentissage de la musique chez les enfants.

B. PROCÉDURE

- ✓ Il est entendu que si je consens à participer à l'étude, je devrai remplir un questionnaire sur mon implication dans les cours de musique, la pratique, les récitals et les autres activités musicales que je fais avec mon enfant, de même que mon histoire familiale en ce qui a trait à la musique. Remplir le questionnaire va me prendre environ 15 minutes.

- ✓ Il est entendu que si je donne mon consentement écrit, mon enfant devra également fournir son consentement verbal avant de participer à l'étude. Au cours de l'évaluation, mon enfant sera invité à réaliser deux tâches musicales à l'ordinateur (60 minutes), deux tâches de mémoire et un tâche d'énigmes (10-15 minutes), et un questionnaire sur son intérêt pour la musique (20 minutes, avec aide au besoin).

- ✓ Il est entendu que tous les questionnaires et tâches seront administrés par un membre de l'équipe de recherche du Dr Penhune.

C. RISQUES ET AVANTAGES

- ✓ Il est entendu que participer à cette étude engendre des risques minimes pour moi et mon enfant. Je comprends que ma participation et celle de mon enfant à cette étude peut potentiellement aider les chercheurs à mieux comprendre les facteurs qui contribuent à l'apprentissage de la musique chez les enfants.

D. CONDITIONS DE PARTICIPATION

- ✓ Il est entendu que ma participation à l'étude est confidentielle. Mes informations personnelles et mon dossier de recherche seront gardés confidentiels dans la mesure de la loi. Seuls les membres autorisés de l'équipe de recherche du Dr Penhune peuvent connaitre mon identité, mais ceux-ci ne divulgueront aucune information à propos de moi, mon enfant, ou notre participation à cette étude. Mon questionnaire de même que les questionnaires et tâches complétés par mon enfant sont confidentiels et accessibles seulement aux membres autorisés de l'équipe de recherche du Dr Penhune.

- ✓ Il est entendu que si je donne mon consentement écrit, mon enfant n'est pas forcé de participer à cette étude et qu'il peut se désister et interrompre sa participation en tout temps sans conséquence défavorable. Je comprends également que la participation de mon enfant n'aura aucune incidence sur ses leçons de musique.

- ✓ Il est entendu que les données de cette étude peuvent être publiées. Toutefois, les données obtenues par moi ou mon enfant seront combinées avec les données d'autres participants dans la publication. Les résultats publiés n'incluront jamais mon nom, le nom de mon enfant, ou toute autre information qui permettrait d'identifier moi ou mon enfant.

- ✓ Si à n'importe quel moment j'ai des questions sur la recherche proposée, je peux communiquer avec le chercheur principal de l'étude, Dr. Virginia Penhune (514-848-2424, poste 7535, virginia.penhune@concordia.ca, http://www-psychology.concordia.ca/fac/penhune/), ou Mme Kierla Ireland, M.A. (514-848-2424, poste 7567, kierla.ireland@gmail.com) du Département de Psychologie de l'Université Concordia. Si à n'importe quel moment j'ai des questions sur mes droits en tant que sujet de recherche, je peux communiquer avec le conseiller éthique de la recherche de l'Université Concordia (514 848-2424, poste 7481, ethics@alcor.concordia.ca)

J'ai lu attentivement la présente entente et j'en comprends la portée. Je consens librement et volontairement à participer à cette étude

Nom : ____

Nom de mon enfant: ____

________ Je consens à ce que mon enfant participe à cette étude.

________ Je ne consens pas à ce que mon enfant participe à cette étude.

J'accepte que le nom et coordonnées de mon enfant soient conservés dans la base de données pour des études futures.

Oui ______ Non ______

Signature: ____

Date: ______________________________

Numéro de téléphone : ________________________

Adresse courriel : __________________________________

Appendix F: Assent Form

ID: ___________

CHILD ASSENT TO PARTICIPATE IN
"DOES STARTING MUSIC LESSONS EARLY PROMOTE SUCCESS FOR CHILDREN?"

Script for obtaining child assent for testing procedures.

My name is {*X*}. We have lots of fun things for you to do today.

Do you know what we are going to be doing today? Well, you're going to get to play a couple of cool music games on the computer. After playing the music games, we are going to do other activities like remembering numbers and solving picture puzzles. Then at the end I'll ask you to read and answer a few questions about your music lessons and I will help you with this part if you need it.

We are going to be taking some breaks in between activities. The thing to remember about all these activities is that sometimes they'll be easy and sometimes they might be harder. That's OK, as long as you try your best.

If you ever want to stop doing **any** of the activities I've talked about, you can just tell me and we'll stop. Nothing bad will happen if you ask me to stop.

Do you understand what we are going to do today? Yes ___ *or* No _____

Do you have any questions for me? Yes ___ *or* No _____

Would you like to participate in the activities I have just described to you? Yes ___ *or* No _____

Are you ready to begin? Yes ___ *or* No _____

Tester's signature: _________________________ Date: ________________

Appendix G: Formulaire de consentement de l'enfant

ID: ___________

<u>CONSENTEMENT DE L'ENFANT À PARTICIPER AU PROJET</u>
<u>« EST-CE QUE DÉBUTER DES LEÇONS DE MUSIQUE EN BAS ÂGE CONTRIBUE AU SUCCÈS DES ENFANTS? »</u>

Script pour obtenir le consentement de l'enfant

Mon nom est {*X*}. J'ai préparé pleins d'activités amusantes pour toi aujourd'hui.

Est-ce que tu sais que nous allons faire aujourd'hui? Tu vas jouer à deux jeux musicaux à l'ordinateur. Tu vas aussi faire d'autres activités comme mémoriser des chiffres et résoudre des casse-têtes. Et pour terminer, je vais te demander de lire et répondre à des questions sur tes leçons de musique. Je vais pouvoir t'aider avec cette partie si tu as besoin d'aide.

Nous allons prendre plusieurs pauses entre les activités. Ce que tu dois te souvenir, c'est qu'il y a certaines activités qui sont plus faciles, alors que d'autres sont plus difficiles. L'important c'est que tu essaies de faire de ton mieux.

Si à n'importe quel moment tu veux arrêter n'importe quel activité dont je t'ai parlé, il suffit de me le dire et on arrêtera tout de suite. Rien de mal ne se passera si tu me demandes d'arrêter.

Est-ce que tu comprends ce que nous allons faire aujourd'hui? Oui ______*ou* Non ______

Est-ce que tu as des questions à me poser ? Oui ______*ou* Non ______

Est-ce que tu veux participer aux activités que je viens de te décrire? Oui _____ *ou* Non ______

Est-ce que tu es prêt/e à commencer? Oui ______ *ou* Non ______

Signature de l'expérimentateur: _________________________ Date: ________________

Appendix H: Debriefing Form

DEBRIEFING FORM
"DOES STARTING MUSIC LESSONS EARLY PROMOTE SUCCESS FOR CHILDREN?"
Laboratory for Motor Learning and Neural Plasticity
Department of Psychology, Concordia University, Dr. Virginia Penhune
Website: http://psychology.concordia.ca/fac/penhune

Most of us are born with the ability to hear, understand, and appreciate music, but we are not all natural born musicians. What helps children to develop into skilled musicians? Is it the age when they start, or the type of musical training they get? What's the role of the child's family? The work in our laboratory is focused on understanding the different factors that can support children's progress and development as it relates to music.

In this experiment, your child performed two musical tasks. For the first task, your child listened to a rhythm on a computer and then tried to repeat the same rhythm by clicking the mouse. Some of the rhythms are more complex than others and can be harder to repeat. As your child practiced this task s/he became more accurate, even for the more difficult rhythms. During the second task, your child listened to a short melody on a computer. Then a second melody played, and your child had to say whether the two melodies were the same or different. The melodies are sometimes the same and sometimes different, and sometimes it can be harder to notice a change. Your child also completed some short cognitive tasks, such as repeating letters and numbers and solving picture puzzles. You filled out a questionnaire about your family musical history, your child's history of music lessons and practice, and other types of musical experiences you might have together. Finally, your child filled out a questionnaire about the reasons s/he is interested in music.

The goal of our study is to identify how different aspects of a child's life support his or her development as it relates to music. To do this, we measured your child's accuracy and timing in the rhythm and melody tasks. These measures will be combined with your and your child's responses on the questionnaires to help us understand which aspects are most important for children's success in music.

Previous studies from our laboratory have shown that starting music lessons earlier may help to build stronger musical skills in adults (see Bailey and Penhune, 2010). We also know that children's motivation for music plays a big role (see Desrochers, Comeau, Jardaneh, & Green-Demers, 2006). In the future, we hope that the results of our studies will inform parents and teachers about the ways they can help children to get the most out of music lessons.

For more information, please refer to our website (see address above) or:

1. Bailey JA and Penhune VB (2010). Rhythm synchronization performance and auditory working memory in early- and late-trained musicians. *Experimental Brain Research,* 204(1):91-101
2. Desrochers, A., Comeau, G., Jardaneh, N., & Green-Demers, I. (2006). L'élaboration d'une échelle pour mesurer la motivation chez les jeunes élèves en piano. *Revue de recherche en éducation musicale*, *24*, 13-33.

Appendix I: Formulaire de Débriefing

DÉBRIEFING
« EST-CE QUE DÉBUTER DES LEÇONS DE MUSIQUE EN BAS ÂGE CONTRIBUE AU SUCCÈS DES ENFANTS? »

Laboratoire de recherche sur l'apprentissage moteur et la neuroplasticité
Département de Psychologie, Université Concordia, Dr. Virginia Penhune
Site internet: http://psychology.concordia.ca/fac/penhune

La plupart d'entre nous ont la capacité d'entendre, comprendre et apprécier la musique, mais nous ne sommes pas tous des musiciens nés. Qu'est-ce qui aide les enfants à développer les compétences d'un musicien? Est-ce l'âge à laquelle ils débutent leur formation musicale ? Quel est le rôle de l'entourage de l'enfant? Notre laboratoire étudie les différents facteurs qui contribuent à l'apprentissage de la musique chez les enfants.

Dans cette étude, votre enfant a réalisé deux tâches musicales. Pour la première tâche, votre enfant a écouté un rythme à l'ordinateur et a ensuite essayé de répéter le même rythme en cliquant sur la souris. Certains de ces rythmes sont plus complexes et peuvent être plus difficiles à répéter. Au cours de cette tâche, votre enfant a acquis de la pratique et est devenu de plus en plus précis, même pour les rythmes plus difficiles. Au cours de la deuxième tâche, votre enfant a écouté deux courtes mélodies à l'ordinateur et devait juger si les deux mélodies étaient identiques ou différentes. À certains moments, les différences entre les deux mélodies sont plus subtiles et rendent la tâche plus difficile. Votre enfant a aussi réalisé de courtes tâches cognitives, comme la résolution d'énigmes et la répétition de lettres et de chiffres. En tant que parent, vous avez également rempli un questionnaire sur les leçons et la pratique de votre enfant, vos antécédents familiaux en ce qui a trait à la musique et les expériences musicales que vous partagez avec votre enfant. Finalement, votre enfant a rempli un questionnaire sur les raisons pour lesquelles il/elle s'intéresse à la musique.

Le but de cette étude est d'identifier les différents aspects de la vie d'un enfant qui favorisent l'apprentissage de la musique. Pour ce faire, nous avons mesuré les capacités musicales de votre enfant, particulièrement sa précision et son sens du rythme. Ces mesures seront combinées avec vos réponses et celle de votre enfant aux questionnaires afin de nous aider à comprendre quels aspects sont les plus importants pour la réussite musicale chez les enfants.

Des études antérieures de notre laboratoire ont démontré que débuter des leçons de musique en bas âge contribue au développement de compétences musicales supérieures chez les adultes (voir Bailey et Penhune, 2010). Nous savons aussi que la motivation des enfants joue un grand rôle (voir Desrochers, Comeau, Jardaneh et Green-Demers, 2006). À l'avenir, nous espérons que les résultats de nos études éclaireront les parents et les enseignants sur la façon dont ils peuvent aider les enfants à tirer le maximum des leçons de musique.

Pour plus d'informations, veuillez consulter notre site internet (voir l'adresse ci-dessus) ou :

1. Bailey JA and Penhune VB (2010). Rhythm synchronization performance and auditory working memory in early- and late-trained musicians. *Experimental Brain Research,* 204(1):91-101
2. Desrochers, A., Comeau, G., Jardaneh, N., & Green-Demers, I. (2006). L'élaboration d'une échelle pour mesurer la motivation chez les jeunes élèves en piano. *Revue de recherche en éducation musicale*, *24*, 13-33.