THE INFLUENCE OF PIANO TRAINING ON COGNITIVE AND NEURAL FUNCTIONING IN OLDER ADULTS

by

SARAH ANNA THORNE

(Under the Direction of Billy R. Hammond)

ABSTRACT

Introduction: This study investigated the effects of a piano training intervention on neural and cognitive functioning in healthy older adults. **Method:** 20 healthy older adults (age 65-85) who had no prior musical experience were recruited. Participants were either randomized into an experimental group that underwent six months of piano training or into a music listening control group. In order to evaluate the effects of training, behavioral cognition testing and high-density electroencephalography (based on evaluating the mismatch negativity, MMN) were conducted. **Results:** Between-subjects analyses at six months found that the piano group exhibited better performance on tasks of inhibition and verbal memory. Within subjects analyses revealed that the piano group improved in verbal memory and reasoning. The piano group also had a greater response to pitch changes as reflected by the MMN. **Conclusion:** Short-term piano training influences verbal memory, executive functioning, and pre-attentive processing of sounds in older adults.

INDEX WORDS: Older adults, Music training, Cognitive function, Mismatch Negativity

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SARAH ANNA THORNE

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SARAH ANNA THORNE

Major Professor: Billy R. Hammond

Committee: Brett Clementz
Roy Kennedy
L. Stephen Miller

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Overview

Musical engagement (whether listening or performing) is a whole brain phenomenon, involving numerous cognitive functions such as learning, memory, emotional processing, and sensory integration (Zatorre & McGill 2005). Music provides an excellent model for studying and promoting the neuroplastic potential of the brain (Herholz & Zatorre, 2012; Jäncke, 2009), with evidence indicating that many observed differences between musicians and non-musicians stem from training as opposed to innate differences between groups. Not only do differences between neural structure and function exist between musicians and non-musically trained individuals, but an impact of training can be observed throughout the lifespan. A growing body of evidence in older adults suggests that even a short period of musical engagement is related to neural and cognitive benefits, thus providing a potential avenue of maintaining such functioning into older adulthood.

Neural Differences between Musicians and Non-Musicians

One method of assessing the potential neuroplastic influence of musical training is to examine structural and functional neurological differences between experienced musicians and non-musicians (for review, see Wan and Schlaug, 2010). In terms of structural differences, Gaser and Schlaug (2003) found musician status was significantly associated with increased gray matter volume bilaterally in primary motor and premotor areas, primary somatosensory areas, anterior superior parietal regions, inferior temporal gyrus, and in the left cerebellum, left inferior frontal gyrus, and left Heschl's gyrus. In addition, musical training is also associated with increased size of the corpus callosum (Schlaug et al., 1995) and increased gray matter in right auditory cortex (Bermudez and Zatorre, 2005).

Evidence for functional differences between musicians and non-musicians exist as well. For instance, greater cortical representation has been observed for the left hand of string musicians (Elbert et al., 1995), as well as for piano tones compared to pure tones (Pantev et al., 1998). Musicians also differ in terms of event-related potentials (AERPs) and event-related fields (AERFs) in the auditory domain (e.g. Pantev et al., 2001; Schneider et al., 2002; & Shahin et al., 2003). More recently, musicians have exhibited enhanced ERPs in tasks involving speech perception and inhibition of non-relevant auditory stimuli (e.g. Kaganovich et al., 2013; Zendel & Alain, 2012). Increased brainstem responses to speech (e.g. Musacchia, Sams, Skoe, & Kraus, 2007; Strait, Kraus, Skoe, & Ashley, 2009; Wong et al., 2007) and musical (e.g. Lee, Skoe, Kraus, & Ashley, 2009; Musacchia et al., 2007) stimuli have also been observed in musician groups.

Musicians also exhibit enhanced sensory-motor integration. For example, transmodal networks were found to be more strongly activated in musicians while observing hand movements related to piano playing (Haslinger et al., 2005). Furthermore, evidence suggests that pianists exhibit activation in motor areas of the brain while listening to a well-rehearsed piece (D'Ausilio, Altenmüller, Belardinelli, & Lotze, 2006; Haueisen & Knösche, 2001). Regions in auditory cortex are also activated when pianists were asked to play a keyboard with no sound (Baumann et al., 2005).

It makes sense, of course, that the brain of a musician differs from that of a non-musician. After all, the brain mediates behavior, and music ability represents a fairly significant category of behavior. It follows then that learning to play a musical instrument would result in neural changes concomitant with the acquisition of a new skill. Since individuals can learn new skills throughout life, the structure of the brain must also be able to change. One question, however, is whether these changes are both measurable and salubrious. Since musical training affects so many areas within the brain, does such training result in generalized benefits? Are such benefits especially meaningful in older adults who are often concerned with cognitive decline?

Impact of Musicianship in a Growing Older Adult Population

Worldwide, the older adult population is growing at an unprecedented rate. By 2050, the global population of older adults is projected to increase to 1.5 billion from approximately 524 million in 2010 (National Institutes on Aging & World Health Organization, 2011). In the United States, the number of older adults between 2010 and 2050 is estimated to double to 88 million, with older adults encompassing approximately 20 percent of the population (Vincent & Velkoff, 2010). Such a dramatic global rise in the number of elders will have a significant impact in numerous areas including caregiving, social security, the work place, and health care. With respect to the latter, among age-related conditions, Alzheimer's disease is anticipated to triple by 2050 (Alzheimer's Association, 2015). With the rise in the number of older adults, it will be important to help as many older adults as possible maintain health and well-being. Lifestyle factors, such as musical engagement, maybe one possible avenue in promoting cognitive health and well-being in older adults (for review see, Kramer et al., 2004).

Evidence suggests that life-long musical training has been associated with numerous cognitive and neural benefits in older adults. For instance, orchestral musicians exhibit less age-related grey matter volume decline in Broca’s area (Sluming et al., 2002). Studies conducted by

Hanna-Pladdy and MacKay (2011) and Hanna-Pladdy and Gajewski (2012) suggest that high-active musicians perform better on tasks of nonverbal memory, naming, and executive processes, and that variability in verbal and visuospatial domains was accounted for by recent and past musical activity. Evidence for cognitive enhancement was also observed in middle aged and older professional musicians on a near-transfer auditory task and far transfer in visuospatial span and cognitive control (Amer et al., 2013). In the face of dementia, memory for musical skills has also been found to be robust enough to remain intact, despite decline in other cognitive functions (Baird and Samson, 2009). Musical engagement has also been associated with a decreased risk of dementia (Verghese et al., 2003) and mild cognitive impairment (Geda et al., 2011).

Training in music may also be related to less age-related declines in perceptual speed and motor music related tasks. For example, musical expertise accounted for a bigger proportion of variance than age for recognition of speeded and slowed melodies (Andrews, Dowling, Bartlett, & Halpern, 1998). Meinz (2000) found that while no interaction between age and experience existed, performance on musical memory and perceptual speed tasks was in part maintained by high levels of musical experience in older adults. In terms of motor functioning, older professional pianists exhibited less motor speed decline on a music performance task through deliberate practice (Krampe & Ericsson, 1996).

Life-long musical training also has benefits in terms of auditory perception in older adults. For instance, professional musicianship is associated with less decline in central auditory processing among older adults (Zendel & Alain, 2012), and is related to increased ability to hear speech in noise, auditory working memory capacity (Parbery-Clark et al., 2011) and auditory scene analysis (For review, see Alain, Zendel, Hutka, & Bidelman, 2014). Recent evidence by Zendel & Alain (2013; 2014), suggests that older musicians also exhibit enhanced activity in attention-dependent ERP components compared to non-musicians, reflecting the idea that older musicians may be better at using endogenous attentive processes for auditory discrimination. Furthermore, brainstem responses, which reflect subcortical processing of auditory information, and cortical neuroelectrical responses show less age-related decline older musicians (Bidelman & Alain, 2015; Pabery-Clark, Anderson, Hittner, & Kraus, 2012).

Taken together, this evidence suggests that years of musicianship is related to less grey matter loss, better performance on cognitive tasks, and enhanced auditory processing. Since treatment for most degenerative disease tends to be largely ineffective, prevention is likely our most effective approach. Musical engagement is a lifestyle factor that could be easily introduced, is innocuous (e.g., does not have the side effects of pharmaceutical intervention) and has potential to meaningfully influence age-related change within the central nervous system. Questions remain, however, about how late is too late? How intensive must the training be? How much change is possible? Are there large individual differences?

Impact of Short-term Musical Training

The differences described above demonstrate the brain's ability to adapt as a result of intensive musical engagement, with training often starting at a very young age and continuing for most of the life course. Behavioral and neurological effects of music are also observed, however, even when training is relatively short-term. For example, in young adults, Lappe et al. (2008; 2011) found enhancement of the magnetic mismatch negativity response (mMMN)[1] after eight sessions of both sensorimotor-auditory training (i.e. piano lessons) and rhythm training, compared to auditory-only training. Auditory sensory-motor co-activation, as measured by DC-

[1] The MMN is a neural response that is usually elicited when deviations occur in a stream of familiar sensory stimuli. It is often assessed with auditory stimuli, and the deviant sound evokes a response that is quantified by subtracting the waveform from the familiar or standard stimulus from the waveform evoked by deviant stimuli.

EEG potentials, was solidified after only five weeks of piano training (Bangert & Altenmüller, 2003). Changes in hippocampal activity were also found after two semesters of aural skills training in music students. Increased performance in executive functioning and verbal intelligence tasks was observed in preschool age children after 20 days of a musical computerized training program (Moreno et al., 2011). Moreno and colleagues (2009), assessing music training in elementary schooled children compared to painting lessons, found enhancements in the N300 component, on reading skills, and discrimination of pitch in speech sounds. François, Chobert, Besson, and Scön (2013) also found differences in speech segmentation ability in children who underwent two years of music training compared to children who took painting lessons.

Evidence of neural change resulting from short-term musical training is also emerging in older adult samples. For example, increased synchrony was observed in the gamma and beta bands for somatosensory steady-state responses in healthy older adults after four to six weeks of piano training. In addition, an anterior shift of these sources was observed after training for both healthy older adults undergoing piano training and one stroke patient who also received training, which may reflect that this processing of vibrotactile stimuli was becoming more automatic with training (Jamali, Fujioka, & Ross, 2014).

Bugos and colleagues (2007) evaluated a six month individualized piano instruction intervention in healthy older adults and found that subjects in the experimental group increased their scores in the domains of working memory and executive functioning. However, in a three month follow-up, after practiced was discontinued, effects had disappeared. In addition to improvements on measures of mood and quality of life, Seinfeld and colleagues (2013) also found that four months of piano training in elders was related to enhanced executive functioning via the Stroop task and a trending improvement in the Trail Making Task part A, an indicator of visual scanning and motor ability. In addition to cognitive changes, rhythmic aspects of music have been related to improved gait steadiness after a short training period (Maclean, Brown, & Astell, 2014).

Even if individuals have engaged in short-term musical training earlier in life, evidence suggests that this training may have a lasting impact on cognitive and neural functioning. For example, White-Schwoch and colleagues (2013) found that elders who had received moderate musical training (4-14 years) before the age of 25 exhibited faster neural timing to consonant-vowel transitions in noise. Furthermore, both young and older adults who received on average 2.4 and 3.81 years of training respectively, performed better on motor tasks compared to participants who had not received music training (Metzler, Saucier, Metz, 2013). Elders with music training early to midlife who had high musical knowledge scored better on a task of episodic memory compared to low musical knowledge participants. The same investigation found that self-reported music reading ability was related measures of episodic memory and verbal fluency (Gooding et al., 2014). Adults with limited training in childhood also exhibit enhanced auditory brainstem responses (Skoe and Kraus, 2012).

Taken together, these findings suggest that the brain is sensitive to remodeling in response to musical tasks, both as a function of life-long devotion to music as well as a result of a brief training period. Most importantly, training effects have been observed in the short-term in older adults, lending evidence to the notion that one does not have to start musical engagement early in life or be a professional musician in order to obtain benefits from music.

Mismatch Negativity (MMN) and Musical Engagement

The present study utilizes the MMN response to assess the potential influence of musical training on neural functioning. The MMN (Näätänen, Gaillard, & Mäntysolo, 1978) is theorized to be a neural detection mechanism within the brain, and is generally elicited when a stimulus deviates from an established pattern in components such as frequency, duration, timbre, and contour (For review, see Näätänen, Paavilainen, Rinne, & Alho, 2007). The MMN peak latency usually ranges between 100-200 ms, and it has the greatest negative deflection in the frontal electrode sites and the greatest positive deflection at the mastoid electrode sites.

Measurement of the MMN is well suited for a musical intervention study. For instance, the MMN has been associated with musical expertise (Kuchenbuch, Paraskevopoulos, Herholz, & Pantev, 2012; Marie, Kujala, & Besson, 2012; Paraskevopoulos, Kuchenbuch, Herholz, & Pantev, 2012; Rüsseler et al., 2001; Tervaniemi et al., 2011; van Zuijen et al., 2005). Stimuli incorporating changes in musical contexts (e.g. pitch, rhythm, transposition, melody) can also be used to elicit the MMN, facilitating fine discrimination between musician groups (e.g. Tervaniemi, Huotilainen, & Brattico, 2014; Vuust et al., 2012). In addition, behavioral auditory discrimination ability is associated with the MMN (Pakarinen et al., 2007). Furthermore, the MMN also varies depending on the type of musical practice strategy used (Seppänen, Brattico, & Tervaniemi, 2007).

The MMN has already been utilized to investigate the impact of musical activities in children. Cross-sectional studies in musically trained children demonstrate enhancement of the MMN to violin tones (Meyer et al., 2011), major and minor chords (Virtala et al., 2012), and speech stimuli (Chobert et al., 2011). A pilot study in elders also found that older musicians exhibited faster MMN to pitch changes and a faster P3a response to deviations in pitch and speech sounds (Nikjeh & Lister, 2012).

In addition to cross-sectional studies, a growing body of longitudinal evidence also supports larger MMNs in musically trained children. For instance, one study which investigated music lessons versus art lessons in musically naive children found larger MMN amplitudes after a year to voice onset time (VOT) and duration of speech stimuli in the music group only (Chobert, François, Velay, & Besson, 2014). Putkinen and colleagues (2014a and 2014b) demonstrated enhanced MMN in young music-exposed children. In one study, MMN and P3a components (elicited from differences between major and minor chords) increased with age to a greater extent in musically trained children (2014b). Using a melodic music MMN paradigm, Putkinen and colleagues (2014a), assessed the MMN and P3a components longitudinally in 7, 9, 11, and 13 year olds. While no differences between musically trained and non-musically trained children were observed at age 9, differences to musical features did begin to emerge at 11 and 13, with musically-trained children at age 11 and 13 showing enhanced MMN to rhythm, mistuning, and timbre deviations, and melody deviations.

Study Objectives

The present investigation seeks to evaluate the potential impact of piano training in healthy older adults using both behavioral and neurological methods, including cognition testing, auditory discrimination testing, and MMN measurement. Older adults who are randomized into the piano training group were expected to exhibit improved performance on cognitive testing and larger MMNs after six months of training compared to elders who are randomized into a music listening group. Performance is hypothesized to return to baseline after a three month follow-up period similar to findings of Bugos and colleagues (2007).

Only two previous studies have assessed the impact of initiating piano playing later in life on cognitive functioning. No study has examined piano training in older adults compared to a music listening control group, nor has piano training in elders been examined using the MMN response.

CHAPTER 2

METHOD

Participants

23 healthy older adults (8 males and 15 females) ranging in age between 65-85 years (mean=71.0; SD=5.56 years) participated in this study. Participants were recruited from Athens, GA and surrounding counties. Participants were excluded if they had a Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) score of less than 24, could read music, had previous musical experience exceeding three years, were left-handed, or if there was a 30 dB difference between the ears at any frequency level tested during the hearing screener (i.e. 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz). The study was approved by the university's Institutional Review Board, and informed consent was obtained from all participants.

Three participants withdrew from the study. Two participants in the piano group voluntarily withdrew from the study over the course of the piano lessons, and one participant was withdrawn by the experimenters after initial enrollment for not meeting the inclusion criteria on the hearing screener. This left 20 participants total that completed the study.

Design

A 2X3 (Group: piano versus listening X Time: pre-training, post-training, three month follow-up) design was used. Behavioral assessments consisted of computerized cognition testing, the Trail Making Tests (TMT Parts A and B) (Reitan & Wolfson, 1985), a musical progression questionnaire, and the Advanced Measures of Music Audiation (AMMA) Gordon, 1989). EEG Measurement was only conducted at baseline and post-intervention. Participants also completed questionnaires on health factors, the Geriatric Depression Scale (Yesavage et al., 1983), and a portion of the SNAQ Appetite Assessment to help account for any influence of these factors on the dependent variables.

Intervention

Participants in this study were randomly placed into either an experimental group receiving piano lessons or an active control group undergoing music listening sessions. Members of each group met weekly with an experimenter for a 30 minute session. Both groups were also asked to complete assignments daily in between music sessions. For the piano group, it was to practice for an half hour each day, and the listening group was asked to listen to a provided compact disc of solo piano music every day for 30 minutes.

. Piano instruction.

Materials.

Hal Leonard Student Piano Library: Adult Piano Method and *Alfred's Basic Adult Play Piano Now!* were used to instruct participants in musical concepts such as notation and dynamics. Participants also learned the Alberti bass pattern of the MMN paradigm, as well as supplementary pieces corresponding to each participant's musical preference.

Concepts.

Throughout the intervention, techniques in the following areas were demonstrated and monitored for proficiency: finger independence, musical fluency, and music theory. Acquisition of finger independence was encouraged during each lesson through monitoring finger tensing and ensuring participants limited movement from non-engaged fingers. In terms of musical fluency, participants were instructed to recognize the notes on the staff ranging from G4 to G3, to play with both hands simultaneously, and to play at a variety of tempo and dynamic markings. Finally, general music theory concepts, such as recognizing key signatures were emphasized throughout the training period.

Listening sessions.

Weekly listening sessions served as an active control group, in which participants were exposed to similar auditory stimuli and social interaction, with the main difference between the groups being the sensory-motor nature of the training in the experimental condition. Active control groups of this type have been employed in other studies (Lappe et al., 2008; 2011; Pantev et al., 2009).

Materials.

Auditory recordings made during the lessons of the experimental group were used to create the stimuli for the listening group. Each week, a recording was selected at random for further processing. During editing, all identifying information of the participant was removed and the audio recording was broken into small segments. Templates of the correctly played segment "as written" were then recorded separately and matched with the lesson segment to create audio pairs.

Procedure.

During each listening session, 20-30 segment pairs were presented and participants were asked to verbally describe to the experimenter whether the pairs sounded the same, or if the pairs sounded different. If participants responded with “different,” they were asked to explain how the pairs differed (e.g. pairs differed in tone, rhythm, steadiness of tempo, intensity, musical style). Over the course of the sessions, musical terms and concepts (e.g. dynamic markings) were introduced to participants to help them better articulate potential differences in segment pairs. Feedback was also given concerning major discrepancies not mentioned by the participant (e.g. a wrong note between the pairs).

EEG Stimuli and Procedure

Auditory stimuli consisted of digital piano tones created in NoteWorthy Composer (NoteWorthy Software, Inc.; Version 2), and were presented in a modified musical multi-feature MMN paradigm originally developed by Vuust and colleages (2011), which itself is based on the 'Optimal' MMN paradigm (Näätänen et al., 2004). Each tone was presented with a sampling frequency of 44,100 Hz, was 200 ms in duration (rise/fall time 5 ms) with an ISI of 5 ms, and was presented at approximately 75 dB.

Standard and deviant stimuli consisted of groupings of four pitches, arranged in an Alberti bass pattern (Figure 1). Standard and deviant stimuli differed only in the third note of the sequence in one of four features: pitch, rhythm, timbre, and pitch + rhythm. The pitch deviant was created by lowering the note by a semitone. The rhythm deviant was created with the tone presented 40 ms earlier in time. The timbre deviant was created by changing the piano sound to a brass sound (trumpet or tuba sound in Noteworthy Composer). Finally, the pitch and rhythm deviants were combined to create the fourth deviant.

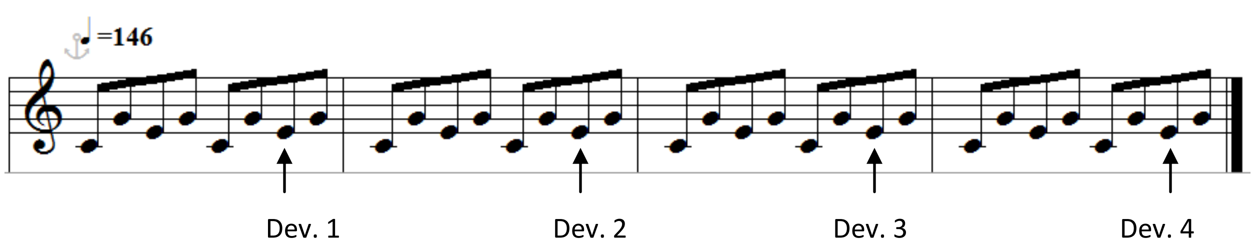


Figure 1. Alberti bass pattern used for MMN paradigm, including the location of deviants. Deviants were randomized within each key, and the key was changed every four measures.

Stimuli were presented binaurally through Etymotic insert earphones (Etymotic Research, Elk Grove Village, IL). Participants were instructed to watch a muted subtitled documentary and to ignore the tones. Presentation software (Version 12.2, www.neurobs.com) was used to present both auditory stimuli and the documentary. Stimuli were presented in eight runs (48 standard trials and 12 trials for each deviant type), lasting approximately five minutes each. Before each run, a string of eight standards preceded the alternating standard/deviant pattern, resulting in 448 total standard trials and 96 trials for each deviant type. Similar to the original musical multi-feature paradigm, stimuli were presented in one of the 12 major keys, which was changed after all deviants were presented once (i.e. every four measures). Deviants were randomly positioned within a given key, and the order of keys for a given run was randomized in Presentation. In addition, stimuli were presented in either the bass or treble clef in separate runs, with the tonic in the bass clef ranging between G2 and F3, and the tonic in the treble clef ranging between B3 and B-flat 4.

EEG Recording and Analysis

Dense array EEG acquisition was conducted using a 256 sensor Geodesic Sensor Net and NetAmps 200 amplifiers. Data were vertex referenced and sampled at 500 Hz with an analog filter bandpass between 0.1-200 Hz. In addition, sensor impedances were maintained below 50 kΩ, a threshold common with high input-impedance amplifiers (Ferree et al., 2001).

EEG data preprocessing and analysis was performed using EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014). Face and neck channels were excluded, leaving 211sensors for data analysis. Channels were visually inspected, and bad channels were interpolated (< 5 % for each participant). Data were offline filtered with a bandpass filter of 1-50 Hz. Independent component analysis (ICA) was conducted for eye-blink and heart rate artifact rejection. Epochs were created 100 ms pre and 400 ms post stimulus onset. Channels were average referenced to include the original reference from CZ and then rereferenced to the average mastoids, which typically show the greatest positive deflection of the MMN response. Data were baseline corrected using the pre-stimulus period. Epochs exceeding a threshold of 100 microvolts were marked for rejection using a simple voltage threshold artifact detection technique in ERPLAB. Epochs were then averaged together, and difference waves were created for each deviant type by subtracting the average standard response from the average deviant response.

Significance of ERPS was conducted in two ways. The first was to use one-sample t-tests to evaluate whether the mean amplitudes of each difference wave was significantly different from 0. The second was to use independent t-tests to assess whether the mean amplitudes of the deviant stimuli differed significantly from the corresponding standard stimuli (i.e. the third note in the group of four notes that preceded the deviant stimulus). While both methods have been utilized in the MMN literature, for the purpose of evaluating the influence of piano training, significant ERPs as assessed by the second method were only considered for further analysis.

When assessing MMN before and after the intervention, mean amplitude and peak latency were assessed at Fz, which shows the most negative amplitude and is commonly evaluated in the MMN literature. Mean amplitude was calculated 40 ms around the peak latency. These measurements were subjected to independent and paired samples t-tests to assess the effect of group (piano and listening) and time (pre- and post-training). The threshold for alpha was set as 0.05.

Behavioral Stimuli and Procedure

Advanced Measures of Music Audiation (AMMA).

The AMMA (Gordon, 1989) was used to assess musical aptitude at baseline and was utilized throughout the study. This test consists of 30 pairs of musical statements and musical answers. The subject's task was to determine whether the musical answer contained a rhythm change, a tonal change, or if the pairs were exactly the same. Total tonal, rhythm and composite scores were calculated for each participant. This test has been widely validated among individuals with and without previous musical training. Scores on the AMMA have also been shown to correlate with aspects of auditory evoked potentials (e.g. Seppänen et al., 2007; Vuust et al., 2012).

Assessment of Self-Reported Musical Skills.

The *Musical Progression Questionnaire*, which was designed by the experimenter (see the full questionnaire in Appendix A), gathered information about the type and degree of musical skills participants acquired during the intervention, and was given at the six month time period. Items required participants to rate on a five point Likert scale how much they agreed or disagreed with statements such as "I acquired musical skills in my music sessions." Participants were also asked to respond to open ended questions about the study. In addition, participants rated the degree of difficulty of their respective music sessions, as well as the general quality of their experience over the course of the study. Finally, participants were asked to rate how often they completed their assignments outside of the lessons (i.e. daily practice for the piano group and daily listening to solo piano music for the listening group).

Cognition testing.

Computerized cognition testing was conducted using CNS Vital Signs (CNS Vital Signs, Inc: Morrisville, NC). This battery consists of the following tasks: verbal memory (VBM), visual memory (VIM), finger tapping test (FTT), symbol digit coding (SDC), Stroop Test, Shifting Attention (SA) Task, Continuous Performance Test (CPT), Perception of Emotions Test (POET), and the Non Verbal Reasoning Test (NVRT). Reaction time, percent accuracy, and standardized scores were produced for each subtest. CNS-VS also generated domain scores which comprised the scores of two or more subtests.

The *Verbal and Visual Memory Tests* consists of immediate and delayed recall of 15 words and images. The *Finger tapping test (FTT)* is a measure of dexterity and assesses motor control. During this task, participants are asked to press the spacebar key on the keyboard with the index finger as quickly as possible for a period of ten seconds. Three trials for the right hand and left hand were obtained. The *Symbol Digit Coding* task is a measure of information processing speed, and requires participants to match template symbols to a corresponding number between 1 and 9. A measure of visual-verbal inhibition, the *Stroop Test* consists of participants responding to colors and words. During the first part of this task, participants are asked to simply make a button press when the word of a color (e.g. "GREEN") is displayed in black text on the screen. In the second part of the task, participants must respond with a key press when the color of the word matches the name of the word. Finally in the third part, participants must respond with a key press when the color of the word does not match the name of the word. The *Shifting Attention Task* is a measure of executive functioning and processing speed. For this task, participants must match a figure based on one of two continually changing rules: either by a corresponding figure's color or by the figure's shape. The *Continuous*

Performance Test (CPT) is a measure of attention that requires participants to only make a key press when the letter "B" appears on the screen in a series of letters. The *Perception of Emotions Test (POET)* is a measure of social acuity and consists of participants making a key press when various facial expressions match the description of an emotion written on the screen. The *Non Verbal Reasoning Test (NVRT)* measures how well participants process visual-abstract concepts, and contains 15 matrices in which participants must select the appropriate answer that best matches the relationship of the matrix.

Participants also completed a Medical Outcomes Survey (MOS), the Neurobehavioral Symptom Inventory (NSI), and a memory questionnaire. These questionnaires were administered in CNS-VS immediately after cognition testing at all three time points to track the health of each participant during the intervention.

In addition to CNS Vital Signs, parts A and B of the TMT (Reitan & Wolfson, 1985) were administered. Part A of the test is a measure of processing speed, while Part B is a measure of complex reaction time and planning ability. In Part A, participants trace a series of numbers 1 through 25. In Part B, participants are asked to trace a series of number and letters, alternating between the two. Reaction time for each part is recorded. Improved performance on this task has been associated with short-term musical training in older adults (Bugos et al., 2007; Seinfeld, et al., 2013).

Statistical Analyses

A 2X3 mixed-model analysis of variance (ANOVA) was used to analyze behavioral data, with the within-subjects factor consisting of time (pretraining, posttraining, and three month follow-up) and the between-subjects factor of group (piano and listening). Independent samples t-tests were used to assess between groups differences. The level for alpha was set to 0.05, and when appropriate the Greenhouse-Geisser correction was used, and the Bonferroni correction was used for multiple comparisons. In addition, corrected p-values and degrees of freedom are presented when Levene's test for equality of variances was significant.

CHAPTER 3

RESULTS

Baseline Group Demographics and Health Characteristics

Descriptive statistics for demographic data are presented in Table 1. Only participants who completed assessments at all three time points are included in tables which are segmented by group. For baseline GDS, one participant was eliminated from the analyses due to incomplete data. For the average times of physical activity per week, four participants did not provide this information at baseline and one participant did not provide it at the six month assessment. Piano and listening groups did not differ in terms of age, $t(18)=-.079$, $p=.938$ or education, $t(18)=-.567$, $p=.578$. The piano group had a higher percentage of females (80%) compared to the listening group (50%).

In terms of health factors, the piano group had a higher number of average times of physical activity per week $t(14)=2.263$, $p=.04$, but the groups did not differ in physical activity at six months, $t(17)=-.296$, $p=.771$. The groups also did not differ in terms of the MMSE, self-reported health, or body mass index (BMI). Analyses of the MOS revealed no significant differences of Time. However, main effects of Group for MOS scores of energy/fatigue, $F(1,18)=6.927$, $p=.017$, and emotional well-being $F(1,18)=7.961$, $p=.011$, were present. Post-hoc independent t-tests showed that the piano group exhibited higher scores on energy at baseline, $t(12.662)=2.545$, $p=.025$, six months $t(13.083)=2.163$, $p=.05$, and at the three month follow-up, $t(18)=2.356$, $p=.03$. Similarly, the piano group also displayed higher scores on emotional well-being at baseline, $t(11.656)=2.883$, $p=.014$, and at six months, $t(18)=3.145$, $p=.006$). While no main effects of Time existed for the GDS, the main effect of Group was significant, $F(1,17)=4.936$, $p=.04$. Follow-up comparisons revealed that the listening group had a higher mean score on the GDS (M=5.1; SD=2.998) at the three month follow-up compared to the piano group (M=1.9; SD=2.234). Data from the NSI, presented in appendix B, showed that listening participants reported more moderate to severe symptoms than piano participants at each of the three time points.

Table 1. Baseline Demographics and Health Factors Data for All Participants

Baseline Subject Characteristics			
	Mean	**Std. Deviation**	**Range**
All Participants			
Age (years)	71.0	5.566	(65-85)
Years of education	17.73	2.585	(13-25)
Gender	Female: 14; Male: 8		
Avg. times physically active per week	4.50	3.24	(0-14)
MMSE	27.4091	1.868	(24-30)
BMI	26.18	5.589	(19.6-39)
GDS	4.4	4.160	(0-13)
Self-reported overall health status (1 = poor, 5 = excellent)	4.0455	.844	(3-5)
Number with Family History of Dementia	5		
Number with Diagnosed with Age-Related Macular Degeneration	1		
Number Diagnosed with Diabetes	2		
Number Diagnosed with Tinnitus	1		
Number Taking Cholesterol Lowing Medications	5		
Number Taking Potentially Cognition Influencing Prescriptions	3		
Number Taking Nutritional Supplements	18		
Piano Participants			
Age (years)	71.45	5.530	(65-83)
Years of Education	17.4	3.273	(13-25)
Gender	Female: 8; Male: 2		
Avg. times physically active per week	6.43	3.735	(3-14)
MMSE	27.2	2.044	(24-30)

BMI	23.51	3.014	(19.6-28.1)
GDS	2.7	3.020	(0-10)
Self-reported overall health status (1=poor, 5=excellent)	4.4	.843	(3-5)
Number with Family History of Dementia	3		
Number with Diagnosed with Age-Related Macular Degeneration	1		
Number Diagnosed with Diabetes	1		
Number Diagnosed with Tinnitus	1		
Number Taking Cholesterol Lowing Medications	1		
Number Taking Potentially Cognition Influencing Prescriptions	0		
Number Taking Nutritional Supplements	9		
Listening Participants			
Age (years)	71.65	5.850	(67-85)
Years of education	18.1	2.132	(16-22)
Gender	Female: 5; Male: 5		
Avg. times physically active per week	3.06	2.200	(0-7)
MMSE	27.6	1.838	(25-30)
BMI	27.72	5.642	(20.4-37)
GDS	6.111	4.859	(1-13)
Self-reported overall health status (1=poor, 5=excellent)	3.8	.789	(3-5)
Number with Family History of Dementia	2		
Number with Diagnosed with Age-Related Macular Degeneration	0		
Number Diagnosed with Diabetes	1		
Number Diagnosed with Tinnitus	0		
Number Taking Cholesterol Lowing Medications	4		
Number Taking Potentially Cognition Influencing Prescriptions	3		
Number Taking Nutritional Supplements	8		

Figure 2 shows audibility curves for frequencies within the EEG stimulus range for each group. The audibility curve for the right ear excludes one piano participant due to an inability to detect frequencies at 125 Hz and 250 Hz. A one-way ANOVA comparing the two groups across frequencies revealed that the two groups did not differ in threshold for frequencies encompassing the EEG stimulus range (i.e. 125, 250, 500, and 1000 Hz).

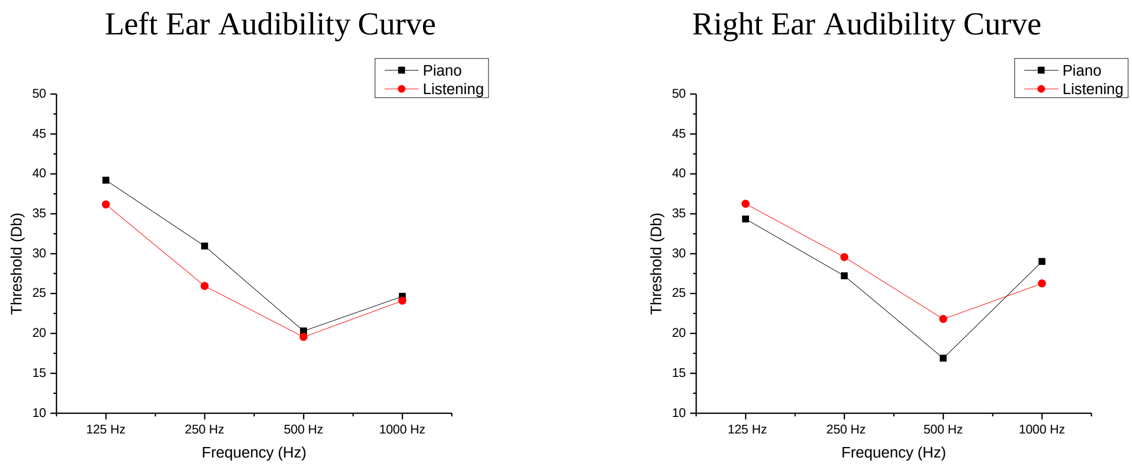


Figure 2. Audibility curves for frequencies encompassing the frequency range of the EEG stimuli.

Cognition Results

For descriptive statistics of the cognition measures assessed, Appendix C displays mean scores and standard deviations for each cognition test at the three time points. To compare baseline cognition performance between the two groups, independent t-tests revealed that the listening group was significantly slower at baseline on part A of the TMT, $t(18)=-2.743$, $p=.013$. However, groups did not differ on any of the other cognition measures assessed at baseline.

Perceptions of Emotions

A mixed ANOVA showed significant main effects of Time for average correct reaction time on the POET, $F(2,36)=5.011$, $p=.012$, and reaction time for the Negative POET subtest, $F(2,36)=3.349$, $p=.046$. However, follow-up Bonferroni corrected pairwise contrasts between each of the three time points showed no significant differences for any of the POET subtests. Between-subjects analysis at each of the three time points indicated that no group differences existed in the social acuity domain score, or any of the subparts of the POET.

Psychomotor Speed

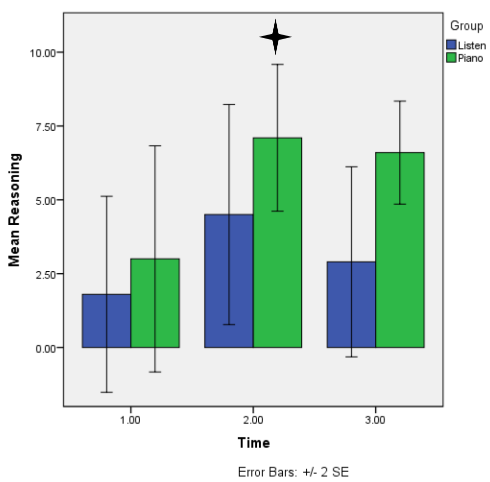
A significant main effect of Time, F(2,36)=6.603, p=.004, and a Group X Time interaction, F(2,36)=6.086,p=.005 was observed for the TMT part A. Follow-up pairwise comparisons collapsing across group revealed that the TMT A was significantly different between baseline and the three-month follow-up (p=.014). Comparisons using paired samples t-tests showed that this effect was found in the listening group only between baseline and the three month follow-up, t(9)=3.706; p=.005. Between-subjects analysis at each time point suggested that the listening group was significantly slower (M=34.884; SD=9.837) than the piano group (M=24.395; SD=7.034) at baseline, t(18)=-2.743, p=.013, but that the groups did not differ at six months or at the three-month follow-up. No significant main effects or interactions were observed for domain reaction time, domain psychomotor speed, or the FTT.

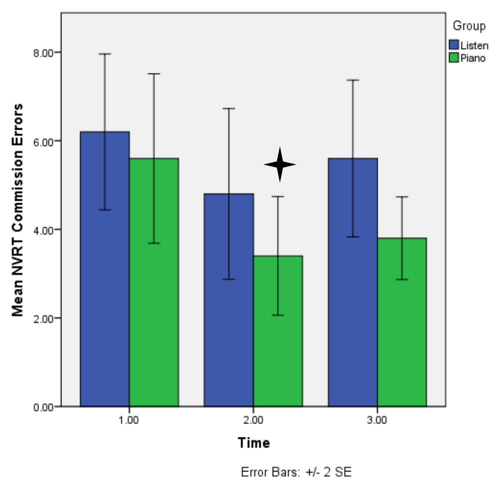
Executive Function

A significant main effect of Time was observed for the reaction time on correct responses for SA, F(2,36)=4.498, p=.018, domain score of reasoning, F(2,36)=5.216, p=.010, NVRT correct responses, F(2,36)=4.720, p=.015, NVRT average reaction time for correct responses, F(2,36)=3.259, p=.05, and NVRT commission errors, F(2,36)=5.368, p=.009. Follow-up Bonferroni corrected pairwise comparisons revealed that differences of Time were only present for domain reasoning, NVRT commission errors, and SA correct RT. Specifically, the piano group had significantly higher scores at six months for domain reasoning (M=7.1; SD=3.928) compared to baseline reasoning (M=3.0; SD=6.055), and also made fewer commission errors on the NVRT at six months (M=3.4; SD=2.119) compared to baseline (M=5.6; SD=3.026). These effects were not maintained after practice was discontinued, as indicated by the absence of significant differences between baseline and the three month follow-up in the piano group for NVRT commission errors, t(9)=1.804, p=.105 and domain reasoning, t(9)=-1.846, p=.098.

Differences in domain reasoning and NVRT commission errors were not observed for the listening group. The listening group did significantly decrease on correct reaction time for SA at the three month follow-up (M=1143.1 ms; SD=164.313) compared to baseline (M=1231.9 ms; SD=180.094), whereas no changes were seen on SA correct reaction time for the piano group. Means for domain reasoning, NVRT commission errors, SA RT correct across the three time points are displayed in Figure 3.

The mixed ANOVA also showed a between-subjects difference for Stroop commission errors, F (1,18)=6.061, p=.024. Follow-up independent t-tests revealed that the piano group made significantly fewer errors (M=0.7; SD=.823) compared to the listening group (M=2.4; SD=1.430) at the six month time point, t(18)=-3.258, p=.004. This difference is shown in Figure 4.





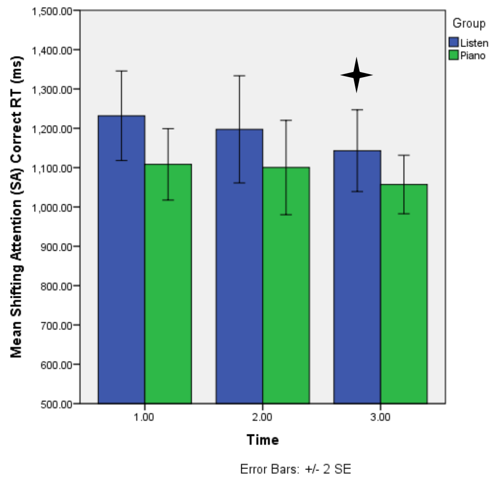


Figure 3. Bar graphs reflecting means at each time point for domain reasoning, NVRT correct responses, NVRT commission errors, and SA correct RT. Error bars reflect standard error. ✦ Indicates means significantly different from baseline for either piano or listening group.

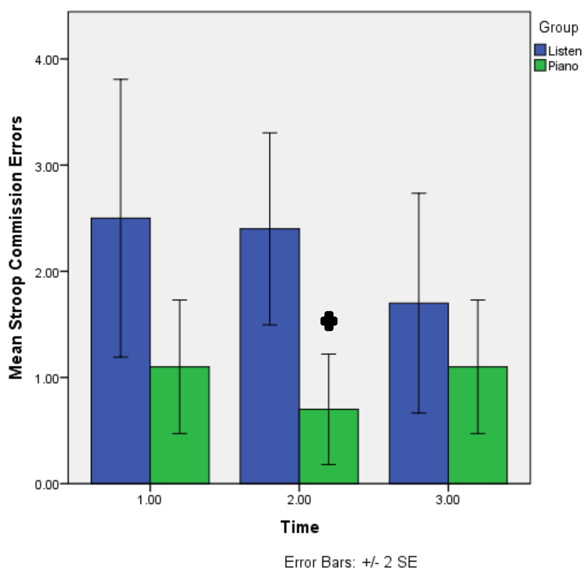


Figure 4. Bar graphs reflecting mean Stroop commission errors at each time point. Error bars reflect standard error. ✚ Indicates significant group differences in score at a specific time point.

Memory

Significant main effects for Time were observed for the number of correct hits on verbal memory (VBM) delayed recall, $F(2,36)=3.85$, $p=.031$ and the composite score of memory, $F(2,36)=3.35$, $p=.046$. However, post-hoc analyses using Bonferroni corrected pairwise comparisons of the three time points collapsing across group revealed no significant changes over time for these two measures.

A main effect of Group was also observed for VBM correct hits on delayed recall, $F(1,18)=5.713$, $p=.028$. Figure 5 shows mean scores for VBM delayed recall across the three time points. Follow-up comparisons revealed that the piano group had significantly more mean hits on verbal memory delayed recall (M=13.5+/; SD=1.43) compared to the listening group (M=11.2; SD=2.251), $t(18)=2.725$, $p=.014$, at the six month assessment only. Paired samples t-tests showed that this effect seems to be due to the piano grouping significantly improving in the number of hits on delayed VBM at six months compared to baseline, $t(9)=-2.512$, $p=.033$. This comparison was not significant for the listening group, $t(9)=-.822$, $p=.432$. Furthermore, this effect in the piano group was maintained at the three month follow-up, as indicated by the number of hits being higher at three month follow-up compared to baseline, $t(9)=-2.586$, $p=.029$. No main effects of Time or Group were observed any of the other VBM subscores or for the visual memory test.

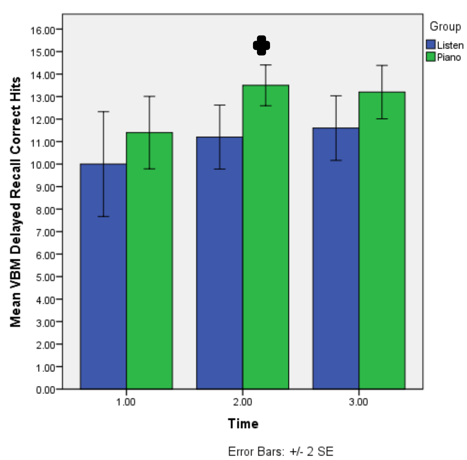
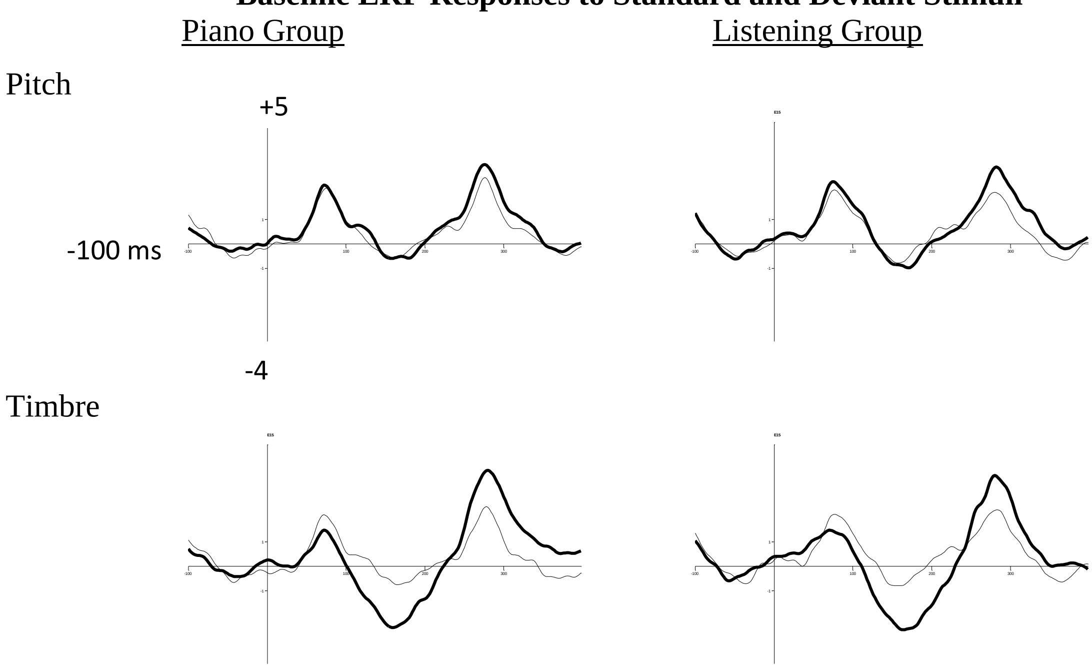


Figure 5. Bar graph for mean correct hits for verbal memory delayed recall across time. Error bars reflect standard error. ✚ Indicates significant group differences in score at a specific time point.

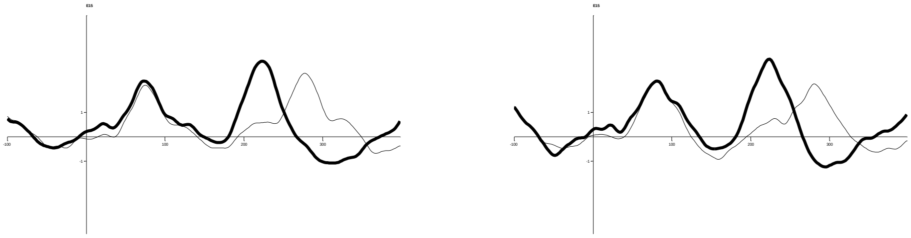
EEG Results

ERP responses to standards and deviants measured at Fz are presented in Figure 6 for baseline and in Figure 7 for the six month measurement. Upon initial inspection of the data, a positive component within the peak latency of the P300 was observed. Therefore, mean amplitudes (calculated similarly to that of the MMN by measuring mean amplitude +/- 20 ms around the peak latency) were also assessed for the latency range between 200-300 ms for standards and deviants to assess possible significance of the P300. Mean amplitudes and latencies for responses to standards, deviants, and difference waves of each deviant type are presented in Table 2. For baseline EEG data, two participants were removed from the analysis (one from the piano group and another from the listening group) due to the presence of artifacts in more than 25 percent of trials.

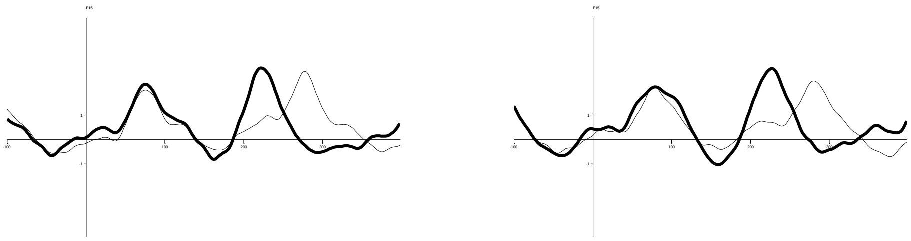
Baseline ERP Responses to Standard and Deviant Stimuli



Rhythm



Pitch and Rhythm Combined



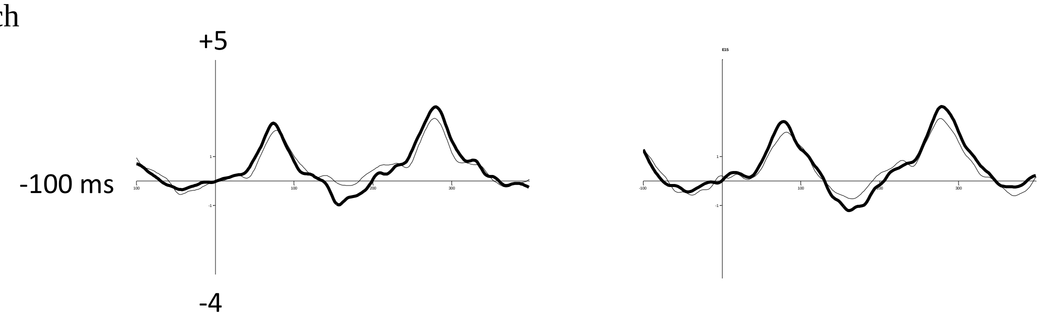
Deviant Standard

Figure 6. Baseline responses to deviants and standards channel approximating Fz for piano and listening groups

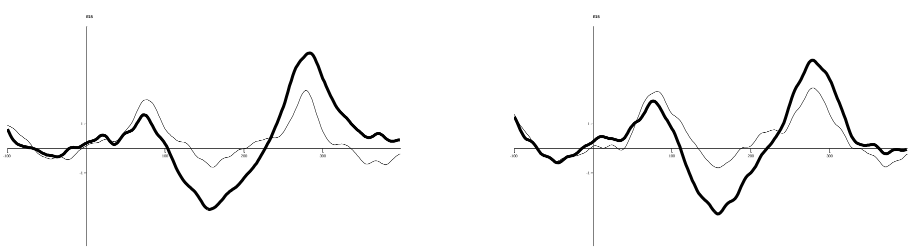
Six Month ERP Responses to Standard and Deviant Stimuli

<u>Piano Group</u> <u>Listening Group</u>

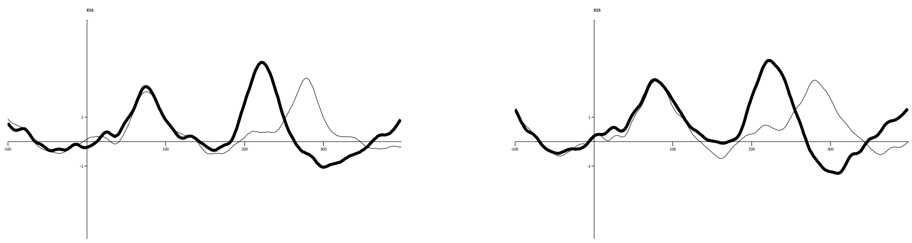
Pitch



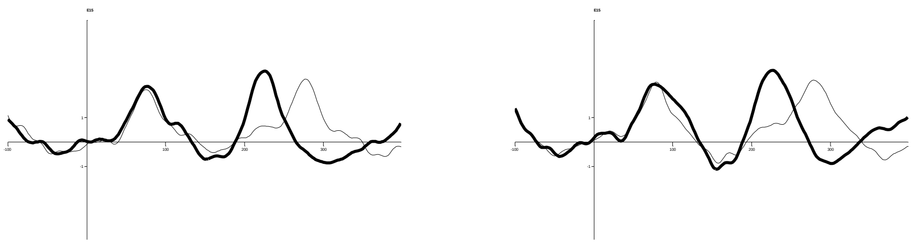
Timbre



Rhythm



Pitch and Rhythm Combined



Deviant Standard

Figure 7. Six month ERP responses to deviants and standards at channel approximating Fz.

Evaluation of the MMN Across All Participants.

Using one-sample t-tests to evaluate the difference of the MMN response from 0, results showed that at baseline three out of the four deviant types elicited the MMN, which included the pitch condition, t(17)=-3.158, p=.006, the timbre condition, t(17)= -10.832, p<.001, and the pitch + rhythm condition, t(17)= -2.377, p=.029. For MMNs measured at six months, the same trend emerged where the mean amplitude of the MMN differed from 0 for pitch, t(19)=-5.374, p<.001, timbre, t(19)=-9.830, p<.001, and pitch + rhythm, t(19)= -3.266, p=.004, but not for rhythm, t(19)= .167, p=.869.

Alternatively, comparing the mean amplitude of standards and deviants for the MMN across all participants, independent t-tests revealed that only the timbre deviant elicited the MMN at baseline, as indicated by the mean amplitude response of the deviant stimulus being significantly greater than the response to the mean amplitude response of the standard stimulus, t(34)=7.689, p<.001. Responses to standard and deviant stimuli did not differ for the pitch condition, t(34)=1.002, p=.323, or the pitch and rhythm combined condition, t(34)=1.451, p=.156. For the rhythm condition, standard stimuli actually elicited a greater negative response compared to the deviant stimuli, t(34)=-2.342, (p=.025). In terms of peak latency, the timbre deviant had a significantly later peak latency than the standard, t(34)=-2.525, p=.031. Peak latency did not differ for any other deviant condition.

At six months, independent t-tests comparing standards and deviants showed that the MMN was elicited for the pitch condition, t(38)=2.845, p=.007 and the timbre condition, t(26.364)=6.537, p<.001. Similar to baseline, responses to standards were significantly greater compared to deviants for the rhythm condition, t(38)=-2.107, p=.042 at six months. In terms of peak latency, none of the standards significantly differed from the deviants in the four deviant conditions.

P300 Data Across All Participants.

One-sample t-tests to evaluate the P300 from 0 at baseline revealed that the mean amplitude for each of the four difference waves was significantly different from 0, including pitch, t(17)=7.072, p<.001, timbre, t(17)=3.760, p=.002, rhythm, t(17)=11.769, p<.001, and pitch + rhythm, t(17)=9.700, p<.001. At six months, mean amplitudes of the P300 difference waves were also significant for pitch, t(19)=2.951, p=.008, timbre, t(19)=3.917, p=.001, rhythm, t(19)=8.658, p<.001, and pitch + rhythm, t(19)= 7.264, p<.001.

Using the second method of analysis, mean amplitude for the deviant stimulus was significantly greater at baseline compared to the standard stimulus, t(34)=-2.978, p=.005, for the timbre condition only. In terms of P300 peak latency, the deviant stimulus occurred significantly earlier compared to the standard for the rhythm, t(26.173)=23.164, p<.001, and pitch + rhythm conditions, t(34)=16.105, p<.001. At six months, the results mimicked those found at baseline, with mean amplitude only differing for the timbre condition, t(38)=-2.909, p=.006, and peak latency occurring earlier in time for the deviant stimuli in the rhythm, t(38)=21.845, p<.001 and pitch + rhythm, t(38)=13.926, p<.001, conditions.

Table 2. Mean Amplitude (μV) and Peak Latency (ms) at Fz for MMN and P300 for All Participants.

		Baseline		6 Month	
		Mean Amplitude (μV)	Peak Latency (ms)	Mean Amplitude (μV)	Peak Latency (ms)
Pitch MMN	Standard	-.5602	157.8813	-.3998	155.3665
	Deviant	-.7512	159.8826	-.9732	164.9193
	Difference Wave	-.4294	163.9544	-.7299	165.6274
Timbre MMN	Standard	-.6394	152.6226	-.6116	156.2608
	Deviant	-2.3780	165.1829	-2.3345	159.5776
	Difference Wave	-1.9088	165.2242	-1.9996	160.5341
Rhythm MMN	Standard	-.6456	158.4336	-.5487	156.7578
	Deviant	-.2487	155.6178	-.1720	155.6397
	Difference Wave	.0494	136.8323	.0178	133.2297
Pitch and Rhythm MMN	Standard	-.3657	150.1794	-.5085	156.8323
	Deviant	-.6675	154.8033	-.7165	163.1304
	Difference Wave	-.4142	148.7853	-.3714	155.1056
Pitch P300	Standard	1.9430	278.7786	2.1452	280.2608
	Deviant	2.6769	278.2816	2.5359	279.7765
	Difference Wave	.8714	273.7819	.4779	267.3790
Timbre P300	Standard	1.9669	279.0822	1.9198	276.5218
	Deviant	3.3473	280.7937	3.3590	280.7330
	Difference Wave	1.4217	280.3382	1.4836	278.0993
Rhythm P300	Standard	1.9651	280.9317	2.1189	278.5340
	Deviant	2.6190	222.6433	2.7647	223.2174
	Difference Wave	2.0872	223.1401	2.3042	222.7702
Pitch and Rhythm P300	Standard	2.0933	275.5348	2.1193	276.5094
	Deviant	2.4786	224.0926	2.4608	226.0497
	Difference Wave	1.7813	222.9329	1.8438	221.9876

Between-Subjects EEG Analysis.

Table 3 displays ERP difference wave mean amplitudes and peak latencies, as well as mean amplitudes for difference scores (i.e. mean amplitude of deviant minus mean amplitude of standard) for the MMN and P300. Each of these reflect measurements at Fz, and only the subset of deviant conditions which elicited either a significant MMN or P300 in the second analysis are shown. At baseline, no group differences were observed for MMN and P300 mean amplitudes or peak latencies for the subset of deviant types assessed. Similarly at the six month post-training EEG measurement, no group differences existed in MMN and P300 mean amplitudes or peak latencies.

Table 3. MMN and P300 Difference Wave Mean Amplitudes and Peak Latencies Measured at Fz for Piano and Listening Groups Pre and Post-Training.

	Group	Mean Amplitude (µV)	Peak Latency (ms)	Mean Amplitude Difference Score (µV)	Mean Amplitude (µV)	Peak Latency (ms)	Mean Amplitude Difference Score (µV)
		Baseline			6 Months		
Pitch MMN	Piano	-.3406	166.9634	-.0589	-.8020	158.6213	-.5908
	Listen	-.5182	160.9453	-.3231	-.6577	172.6335	-.5560
Timbre MMN	Piano	-1.8727	162.7672	-1.6508	-2.0051	155.2670	-1.7691
	Listen	-1.9450	167.6812	-1.8264	-1.9941	165.8012	-1.6769
Timbre P300	Piano	1.5640	277.2326	1.5578	1.6599	275.4410	1.7501
	Listen	1.2793	283.4439	1.2030	1.3074	280.7576	1.1283
Rhythm P300	Piano	2.0854	222.1049	.4469	2.2506	220.9566	.6352
	Listen	2.0889	224.1752	.8610	2.3577	224.5839	.6564
Pitch and Rhythm P300	Piano	1.7538	223.2918	.2090	1.7453	223.9379	.2948
	Listen	1.8089	222.5740	.5614	1.9422	220.0373	.3881

Within-Subjects EEG Analysis.

Paired-samples t-tests to assess possible within-subjects differences in the MMN and P300 for the subset of deviant conditions analyzed revealed that the mean amplitude for the MMN difference wave of pitch was significant for the piano group only using a one-tailed test, $t(8)=2.276$, $p=.026$. Similarly to the difference waves, a within-subjects analysis was also conducted on the calculated difference scores of mean amplitude (i.e. mean amplitude of deviant-mean amplitude of standard). Paired samples t-tests revealed that the piano group exhibited differences in MMN mean amplitude for pitch using a one-tailed test, $t(8)=3.779$, $p=.003$. No within group differences were observed for the listening group. MMN response for pitch for pre and post-training are depicted in Figure 8. Furthermore, no within-subjects differences were observed for peak latency for any of the deviant conditions.

Piano Baseline and 6 Month Difference Waves

Pitch

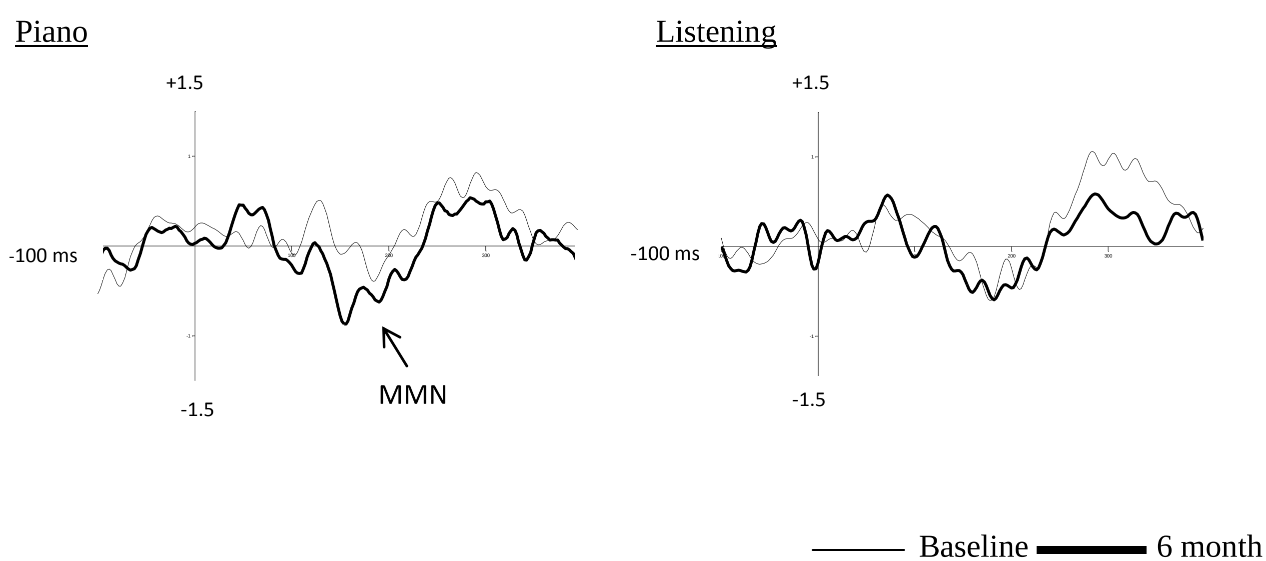


Figure 8. ERP difference waves measured at Fz for pitch at pre- and post-training.

Music Aptitude, Self-Reported Musical Skill Acquisition and Engagement

In terms of musical aptitude, scores on the AMMA are presented in Table 4, with percentile scores reflecting normed values for non-music majors. A mixed ANOVA showed that no main effects for Group or Time, or interactions existed for any of the AMMA subscores. While music aptitude did not differ between the two groups, at baseline the maximum hours of music listening per day was greater, t(10.1160=-2.968, p=.014 for the listening group (mean=6.11, SD=5.13) compared to the piano group (mean=1.14, SD=1.22). However, the groups did not differ in terms of music listening at the six month measurement, t(10.735)=-1.543 p=.152.

Table 4. AMMA Scores at Each of the Three Testing Time Points

	Group	**Baseline** Mean (+/-SD)	**6-Month** Mean (+/-SD)	**3-Month Follow up** Mean (+/-SD)
Tonal Score	All	24.4 (+/- 4.887)	24.2 (+/-4.934)	25.4 (+/-4.773)
	Piano	21.6 (+/- 2.989)	23.6 (+/- 4.903)	24.0 (+/- 4.899)
	Listen	26.4 (+/- 5.358)	24.7 (+/- 5.165)	26.8 (+/-4.442)
Tonal Percentile	All	51.5 (+/- 23.894)	50.2 (+/-23.853)	56.0 (+/-23.221)
	Piano	37.6 (+/- 15.421)	48.1 (+/- 25.190)	49.1 (+/-24.260)
	Listen	60.8 (+/- 25.638)	52.2 (+/- 23.607)	62.8 (+/-21.107)
Rhythm Score	All	26.9 (+/- 3.658)	26.8 (+/- 4.598)	28.0 (+/- 4.472)
	Piano	26.2 (+/- 1.989)	27.1 (+/- 5.065)	26.6 (+/- 4.599)
	Listen	27.3 (+/- 5.056)	26.4 (+/- 4.326)	29.4 (+/- 4.088)
Rhythm Percentile	All	49.8 (+/- 18.082)	49.1 (+/- 22.357)	54.9 (+/- 21.981)
	Piano	46.0 (+/- 9.944)	50.9 (+/- 24.456)	48.1 (+/- 22.815)
	Listen	51.5 (+/- 24.932)	47.2 (+/- 21.202)	61.7(+/- 19.917)
Total Score	All	51.4 (+/- 7.986)	50.9 (+/-8.837)	53.4 (+/- 8.893)
	Piano	47.8 (+/- 4.517)	50.7 (+/- 9.627)	50.6 (+/- 9.180)
	Listen	53.7 (+/- 9.911)	51.1 (+/- 8.491)	56.2 (+/- 8.080)
Total Percentile	All	50.4 (+/- 21.380)	49.2 (+/-23.621)	55.1 (+/- 22.858)
	Piano	40.4 (+/- 13.550)	49.1 (+/- 25.813)	47.8 (+/- 24.453)
	Listen	56.4 (+/- 25.409)	49.3 (+/- 22.618)	62.3 (+/- 19.704)

Data from the *Musical Progression Questionnaire* are presented in Table 5. Ranging from "1-Completely Disagree" to "5-Completely Agree," both groups had average responses between "4-Agree" and "5-Completely Agree" in terms of how engaging they found the weekly music sessions. These averages did not differ from one another, t(17)=-.169, p=.868. However, members of the piano group were more likely to agree that they acquired musical skills in the sessions compared to the listening group, t(18)=2.176, p=.043. In addition, the piano group rated the music sessions as more difficult, t(13.420)=-3.881, p=.002, (1=”Very Difficult, 5=”Very Easy”). Given the choice of responding from "1-Never" to "5-Always," both groups completed their assignments outside the weekly sessions often, and did not differ in terms of self-reported frequency of completion, t(18)=-.361, p=.722. Finally, in terms of rating the overall experience of the musical sessions from "1-Poor" to "5-Excellent," the two groups did not statistically differ in their responses, t(10.587)=-1.714, p=.116.

Table 5. Group Descriptive Statistics and p-values for Musical Progression Questionnaire.

	Group	Mean	Std. Deviation	P-Value (2-tailed)
Weekly Music Session Engagement	Piano	4.4444	.72648	.868
	Listen	4.5000	.70711	
Acquired Musical Skills Rating	Piano	4.5000	.70711	**.043***
	Listen	3.5000	1.26930	
Level of Session Difficulty	Piano	2.6500	.47434	**.002****
	Listen	4.0000	.94281	
Frequency Completing Weekly Assignments	Piano	4.4000	.69921	.722
	Listen	4.5000	.52705	
Overall Experience Rating	Piano	4.0000	1.41421	.116
	Listen	4.8000	.42164	

Table 6 summarizes participant responses to open ended questions on the *Musical Progression Questionnaire*. In terms of factors motivating participation in the study, the two groups listed similar reasons that motivated participation, such as a general interest in learning a new skill, interest in music, and interaction with study personnel. For specific musical skills obtained during the study, piano participants were more likely to report skills related to learning to play piano, such as reading music, general piano knowledge, and hand coordination. Contrastingly, responses of listening participants were more likely to be listening oriented, with responses such as obtaining better listening habits, improvement in identifying musical details and genres, and increasing music appreciation.

Table 6. Open-ended Reponses from the Musical Progression Questionnaire

Question	Piano	Listening
Factors motivating study participation	• General interest/learn new skill • Interest in research • Learn more about music • Learn to play piano • Relationship with instructor/experimenters • Valuable feedback on progress • Preference for listening group	• General interest in learning something new • interest in music • Support research • To learn piano • Take home listening assignment • Improve cognition • Interacting with experimenters
Musical Skills Acquired	• Read music (identify notes on piano, read treble and bass clef, fingering, dynamics, expression, rhythms) • Ability to play pieces at appropriate difficulty level • General piano knowledge • Coordinate hands playing together	• Better listening habits • Increased ability to identify details of music • Identify genres • Music appreciation
Other comments about the study	• Any progress is real progress • Mixture of frustration and fascination • Wonderful experience • No idea what to expect, and found process extremely enjoyable • Really didn't enjoy the lessons! • Found right and left hand together challenging, but made some progress • My ability is low, but interest and desire to continue lessons is high; All involved with study were extremely kind and professional	• Wants to try piano • Interesting to hear progress of participants in the piano group • Thoroughly enjoyed experience • Enjoyed time with experimenter • Loved it!

CHAPTER 4

DISCUSSION

Overview of Main Findings

The purpose of the present study was to assess the potential impact of piano training in healthy older adults. The primary findings of this study are that piano training was associated with changes in aspects of cognitive functioning, particularly in reasoning and verbal memory, as well as changes in ERP responses to musical stimuli. Furthermore, these effects were present in comparison to an active music listening control group.

Regarding findings related to executive functioning, between-group differences showed that at the six month time point, the piano group had significantly better scores compared to the listening group for Stroop commission errors. Improvements in domain reasoning and in NVRT commission errors were also observed for the piano group only between baseline and immediately after the six month training period. A previous study in older adults also found enhancements in aspects of the Stroop in relation to music training (Seinfeld et al., 2013). While the number of correct responses did not differ between the piano and listening groups in this study, the number of errors made in the piano group was significantly smaller, perhaps reflecting better inhibition in the piano group. Similar to Bugos and colleagues (2007), these effects were not observed at the three month follow-up, after practice was discontinued.

The piano group also had more correct responses for delayed verbal memory recall compared to the listening group. Within-subject comparisons revealed that the correct hits for delayed memory recall were significantly different between baseline and six months for the piano group only. An association between music training and enhanced verbal memory has been observed in other studies (e.g. Chan, Ho, & Cheung, 1998; Ho et al., 2003; Rickard et al., 2010). Interestingly, this enhancement in verbal memory was maintained at the three month-follow-up.

Piano training in this study was also associated with changes in the MMN, reflecting better preattentive processing of sounds. While no group differences existed on the subset of features analyzed, paired samples t-tests revealed that the piano group had significantly larger MMN mean amplitude for the pitch condition. No significant within subject differences in mean amplitude were observed for the listening group. Other studies have shown enhancement of the MMN to major and minor pitch changes in children after music engagement (e.g. Putkinen et al., 2014b, Virtala et al., 2012). The findings of the current study extend the results of these previous studies to older adults.

These major findings are also supported by self-report data collected during the study. Participants in the piano group were more likely to report that they gained musical skills and that the weekly music sessions were more challenging. For example, the piano group was more likely to report obtaining skills related to learning an instrument, such as identifying the notes on the piano and staff, learning rhythms, being able to use dynamics and musical expression, and hand coordination. Contrastingly, the listening group reported improving in the ability to identify genres and fine details of music, as well as a better sense of music appreciation. These data lend itself to the idea that the challenge of learning the skills required to play an instrument may be more impactful on cognitive and neural functioning compared to music listening alone.

In addition, it is unlikely that the findings could be explained by the level of engagement between each group. Both groups rated the level of engagement in the weekly music sessions and overall experience in the study relatively high, and did not differ in their self-reported compliance of completing the assigned weekly assignments of either daily practicing or daily listening to solo piano music. The groups also had similar motivating factors for enrolling in the study, which included a general interest in learning a new skill, an interest in research, a desire to learn the piano, and a relationship with music instructor and study personnel.

One strength of the present experimental design is its control for social interaction. A relationship with a music teacher can be a powerful motivator in learning an instrument. In fact, both groups in the present study cited enjoyment with interacting with study personnel when asked to provide general comments on the *Musical Progression Questionnaire*. However, although both groups met with individual experimenters on a weekly basis, the group undergoing piano training exhibited enhancements in cognitive and neural functioning not observed in the listening group.

Limitations

Perhaps the primary limitation of this study was the nature of the sample. The initial sample size was only 23 participants, and only 20 of those completed the study. Everyone who completed the study was Caucasian, and the average education level of the sample was high. The small number of participants also made equating the piano and listening groups on potential confounding factors such as gender and health factors somewhat challenging. However, correlations between these factors and dependent variables exhibiting significant effects at six months (i.e. Stroop commission errors, NVRT commission errors, domain reasoning, correct hits on delayed verbal memory recall, and MMN pitch difference wave and difference score) showed that gender and MOS raw scores of energy/fatigue and emotional well-being measured at the six month time point were not correlated with any of these dependent variables.

Unexpectedly, piano participants also exhibited better performance on the TMT A at baseline, and the listening group showed faster RT for correct responses for SA at the three month follow-up compared to baseline. Given that these differences were not also present at the six-month visit (arguably when any potential intervention effects on cognition measures would be the most influential), it is likely that other between subjects factors, other than the intervention, are potentially influencing these observed differences between the listening and piano groups. Taken together, the listening and piano-trained groups were generally well-matched. Differences existed between the groups, but those differences were not systematic nor were they meaningfully related to our outcome measures in a way.

Future Directions

The current study found relations between piano training and measures of cognitive and neural functioning in high functioning older adults. However, a better understanding of the aspects of cognition potentially influenced by musical training is needed. In the two previous studies conducted on the influence of short-term piano training in elders, Bugos and colleagues (2007) found that training was related to measures of working memory and executive functioning, whereas Seinfeld et al. (2013) found differences in the TMT A, an indicator of visual scanning and motor ability, along with a task of executive functioning. While the present study extends the findings of these previous studies to include enhancements on cognitive function, the influence of piano training on different types of cognitive tests measured between these studies is not consistent. Therefore, more replication is needed to further elucidate what potential aspects of cognitive functioning music training may be influencing.

Another future avenue for this line of research is to further study the impact of music learning on the MMN. While the current study revealed changes in the pitch condition, it would be worth further investigation to see if ERP responses to other types of deviants and degrees of change within different types of deviants are more sensitive to musical training in older adults.

Finally, another possible line of inquiry would be to further examine the effects of musical training in different populations. One interesting question would be to assess the potential impact of music learning in older adults at risk for dementia, and how impactful a traditional lesson model may be on cognitive performance in this population.

Conclusions and Implications

In the current study, associations between short-term piano training and measures of cognitive and neural functioning were observed in older adults who were musical novices prior to participating in the study. This finding is quite remarkable, and suggests that one may not have to spend years of dedication to music in order to obtain benefits from musical engagement. In addition, impacts on cognition and ERP responses were observed in comparison to a music listening group which received similar social interaction to those participants who engaged in piano lessons. This finding further supports the idea that perhaps the challenge and multisensory nature of learning music are important to observed enhancements in cognitive and neural functioning. Furthermore, to the author’s knowledge, this study was also the first to assess the influence of short-term piano training on the MMN in older adults. Findings from the present study suggest that changes in preattentive processing to sound changes are observable after only a relatively short period of training in this population. In sum, musical engagement may be one potential method of enhancing cognitive and neural functioning in older adults.

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APPENDIX A

Musical Progression Questionnaire

Instructions: These questions pertain to the music session (i.e. either piano lessons or music listening) that you are participating in. For each question, please select the answer choice that most closely matches your opinion.

1. **In general, I found my weekly music sessions engaging.**
   - ❑ Completely disagree
   - ❑ Disagree
   - ❑ Neutral
   - ❑ Agree
   - ❑ Completely Agree

2. **What factors motivate you to participate in your music sessions?** ______________________

   ____

3a. I acquired musical skills in my music sessions.
   - ❑ Completely disagree
   - ❑ Disagree
   - ❑ Neutral
   - ❑ Agree
   - ❑ Completely Agree

3b. If applicable, list musical skills____

4. **I found the level of difficulty of my weekly music session to be**
   - ❑ Very difficult
   - ❑ Difficult
   - ❑ Average
   - ❑ Easy
   - ❑ Very easy

5. **How often did you complete your assigned homework?**
   - ❑ Never
   - ❑ Rarely
   - ❑ Sometimes
   - ❑ Often
   - ❑ Always

6. **Overall, how would you rate your experience in your musical sessions?**
   - ❑ Poor
   - ❑ Fair
   - ❑ Satisfactory
   - ❑ Good
   - ❑ Excellent

7. **Other comments?**

   ____
   ____
   ____

APPENDIX B

Moderate and Severe Symptoms from the NSI

	Group	Baseline		6-Month		3-Month Follow up	
		Moderate	Severe	Moderate	Severe	Moderate	Severe
Feeling Dizzy	Piano						
	Listen			1			
Loss of Balance	Piano						
	Listen	1	1	4		2	1
Poor Coordination	Piano						
	Listen	2		3	1	1	1
Headaches	Piano						
	Listen			2			
Nausea	Piano						
	Listen					1	
Vision Problems	Piano						
	Listen	2		1		1	
Sensitivity to light	Piano						1
	Listen		1	1	1	2	1
Hearing difficulty	Piano			1		1	
	Listen	4		4	1	2	1
Sensitivity to Noise	Piano					1	
	Listen	2	1	4		2	
Numbness	Piano						
	Listen			2		3	
Change in Taste and/or Smell	Piano						
	Listen						
Loss of Appetite or Increased Appetite	Piano						
	Listen						
Poor Concentration	Piano						
	Listen	1		2		1	
Forgetfulness	Piano						
	Listen	1		1	1	2	
Difficulty Making Decisions	Piano			1		1	
	Listen			2		1	

Slowed Thinking, Difficulty Getting Organized, Can't Finish Things	Piano						
	Listen			1			
Fatigue	Piano						
	Listen			2	1	1	1
Difficulty Falling or Staying Asleep	Piano			1		2	
	Listen		1	1	1	3	1
Feeling Anxious or Tense	Piano						
	Listen			1		2	1
Feeling Depressed or Sad	Piano						
	Listen	1		1		2	
Irritability	Piano						
	Listen	1				1	
Poor Frustration Tolerance, Feeling Easily Overwhelmed	Piano						
	Listen					1	

APPENDIX C

Average Raw Score for Social Acuity and POET.

	Group	**Baseline** Mean (+/-SD)	**6-Month** Mean (+/-SD)	**3-Month Follow up** Mean (+/-SD)
Social Acuity Domain Score	All	8.8 (+/-1.893)	8.5 (+/-1.987)	9.4 (+/-1.875)
	Piano	8.8 (+/-1.687)	8.8 (+/-1.476)	9.7 (+/-2.214)
	Listen	9.1 (+/-2.132)	8.2 (+/-2.440)	9.1 (+/-1.524)
POET Avg. Correct RT	All	1140.3 (+/-192.523)	1096.6 (+/-129.719)	1055.1 (+/-146.355)
	Piano	1100.7 (+/-153.9467)	1118.5 (+/-85.400)	1059.8 (+/-62.930)
	Listen	1200.4 (+/-228.491)	1074.7 (+/-164.818)	1050.4 (+/-203.004)
POET Correct Responses	All	11.2 (+/-1.006)	11.3 (+/-1.019)	11.5 (+/-.607)
	Piano	11.0 (+/-1.054)	11.4 (+/-1.075)	11.5 (+/-.707)
	Listen	11.7 (+/-.483)	11.1 (+/-.994)	11.5 (+/-.527)
POET Omission Errors	All	0.8 (+/-1.006)	0.75 (+/-1.019)	0.5 (+/-.607)
	Piano	1.0 (+/-1.054)	0.6 (+/-1.075	0.5 (+/-.707)
	Listen	0.3 (+/-.483)	0.9 (+/-.994)	0.5 (+/-.527)
POET Commission Errors	All	2.4 (+/-1.891)	2.75 (+/-1.552)	2.1 (+/-1.619)
	Piano	2.2 (+/-2.098)	2.6 (+/-1.430)	1.8 (+/-1.874)
	Listen	2.6 (+/-1.897)	2.9 (+/-1.729)	2.4 (+/-1.350)
Positive POET RT	All	1075.9 (+/-201.669)	1014.6 (+/-134.467)	995.95 (+/-133.198)
	Piano	1022.1 (+/-184.782)	1013.0 (+/-80.895)	981.3 (+/-61.943)
	Listen	1160.0 (+/-209.530)	1016.1 (+/-177.827)	1010.6 (+/-182.047)
Positive POET Correct Hits	All	5.8 (+/-.429)	5.85 +/-.366)	5.9 (+/-.308)
	Piano	5.6 (+/-.516)	5.8 (+/-.422)	5.8 (+/-.422)
	Listen	5.9 (+/-.316)	5.9 (+/-.316)	6.0 (+/-0)
Negative POET RT	All	1216.2 (+/-224.028)	1188.5 (+/-170.636)	1118.65 (+/-187.744)
	Piano	1181.8 (+/-150.325)	1233.4 (+/-150.969)	1142.2 (+/-139.625)
	Listen	1243.8 (+/-284.506)	1143.6 (+/-184.924)	1095.1 (+/-231.699)
Negative POET Correct Hits	All	5.4 (+/-.908)	5.45 (+/-.826)	5.6 (+/-.598)
	Piano	5.4 (+/-.843)	5.6 (+/-.843)	5.7 (+/-.675)
	Listen	5.8 (+/-.422)	5.3 (+/-.823)	5.5 (+/-.527)

Baseline CNS-VS and TMT Data

	All RPs	**Piano RPs**	**Listener RPs**
	Mean (+/- SD)	Mean (+/- SD)	Mean (+/- SD)
TMT Part A	28.7827 (+/- 9.919)	24.395(+/- 7.034)	34.884(+/- 9.837)
TMT Part B	59.9145 (+/-22.380)	54.448 (+/- 21.953)	66.652(+/- 22.960)
Reaction Time (RT)	695.2727 (+/-94.409)	695.2(+/- 84.715)	712.9 (106.223)
Psychomotor Speed	146.1364 (+/-22.865)	147.1(+/-21.850)	140.5(+/-23.670)
CPT Correct Responses	39.9091 (+/-0.294)	39.9(+/- 0.316)	39.9(+/- 0.316)
CPT Omission Errors	.0909 (+/- 0.294)	0.1(+/- 0.316)	0.1(+/- 0.316)
CPT Commission Errors	.4545 (+/- 0.596)	0.3(+/- 0.483)	0.6(+/- 0.699)
CPT Choice RT Correct	451.5455 (+/- 59.756)	453.0(+/- 54.898)	461.4(+/- 65.117)
Stroop Simple RT	308.0000 (+/- 49.970)	304.8(+/- 48.746)	323.3(+/- 48.630)
Stroop Complex RT Correct	638.0909 (+/- 67.950)	644.2(+/- 61.949)	640.0(+/- 80.010)
Stroop Correct RT	751.7727 (+/- 131.038)	745.6(+/-117.796)	785.1(+/- 142.495)
Stroop Commission Errors	1.7727 (+/- 1.660)	1.1(+/-0.994)	2.5(+/- 2.068)
SA Correct Responses	45.0909 (+/- 14.356)	45.4(+/- 16.998)	42.4(+/- 12.258)
SA Errors	9.0455 (+/- 8.753)	9.4(+/- 10.895)	9.6(+/- 7.230)
SA Correct RT	1153.0000 (+/-171.612)	1108.3(+/- 143.587)	1231.9(+/- 180.094)
FTT Right Taps Average	50.4091(+/- 8.500)	50.0(+/- 9.006)	49.6(+/- 8.462)
FTT Left Taps Average	48.0909(+/- 7.204)	48.3(+/- 7.088)	46.6(+/- 7.397)
Composite Memory	96.0455(+/- 8.644)	96.1(+/- 9.904)	94.9(+/- 8.225)
Verbal Memory (VBM)	51.5455(+/- 5.171)	51.6(+/- 4.719)	50.8(+/- 6.052)
Visual Memory (VIM)	44.5000(+/- 5.458)	44.5(+/- 6.258)	44.1(+/- 5.280)
Reasoning	2.9091(+/- 5.528)	3.0(+/- 6.055)	1.8(+/- 6.055)
Executive Functioning	36.0455(+/- 22.586)	36.0(+/-27.410)	32.8(+/- 18.914)
Complex Attention	11.3636(+/- 9.786)	10.9(+/- 11.733)	12.8(+/- 8.574)
Cognitive Flexibility	34.2727(+/- 23.125)	34.9(+/- 27.847)	30.3(+/- 19.528)
VBM Correct Hits Immediate	12.8182(+/- 2.107)	12.2(+/- 2.658)	13.2(+/- 1.549)
VBM Correct Passes Immediate	14.0000(+/- 1.155)	13.9(+/-0.876)	14.0(+/- 1.491)
VBM Correct Hits Delayed	10.9091(+/- 3.146)	11.4(+/- 2.547)	10.0(+/- 3.682)
VBM Correct Passes Delayed	13.8182 (+/- 1.563)	14.1(+/- 1.197)	13.6(+/- 1.897)
VIM Correct Hits Immediate	11.8636(+/- 2.100)	11.6(+/- 2.591)	12.1(+/- 1.792)
VIM Correct Passes Immediate	11.1364(+/- 2.696)	11.2(+/- 2.974)	10.7(+/- 2.627)
VIM Correct Hits Delayed	11.1364(+/- 2.850)	11.0(+/- 3.621)	11.4(+/- 2.271)
VIM Correct Passes Delayed	10.3636(+/- 2.517)	10.7(+/- 2.312)	9.9(+/- 2.846)
SDC Correct Responses	47.8182(+/- 9.560)	49.0(+/- 9.177)	44.6(+/- 9.640)
SDC Errors	1.3182(+/-1.701)	0.9(+/- 0.876)	1.8(+/- 2.300)
NVRT Correct Responses	8.5455(+/- 2.738)	8.6(+/- 3.062)	8.0(+/- 2.539)
NVRT Average Correct RT	4672.6364 (+/- 1062.243)	4677.6(+/- 993.421)	4512.7(+/- 1194.695)
NVRT Commission Errors	5.6364(+/- 2.838)	5.6(+/- 3.026)	6.2(+/- 2.781)
NVRT Omission Errors	0.8182(+/- 0.733)	0.8(+/- 0.632)	0.8(+/- 0.919)

6 Month CNS-VS and TMT Data

	All RPs	**Piano RPs**	**Listener RPs**
	Mean (+/- SD)	Mean (+/- SD)	Mean (+/- SD)
TMT Part A	26.8755 (+/-7.457)	24.4280 (+/- 3.730)	29.3230 (+/- 1.180)
TMT Part B	32.54 (+/-17.404)	49.9290 (+/- 15.637)	57.8340 (+/- 18.979)
Reaction Time (RT)	698.9 (+/-71.829)	693.9 (+/- 49.633)	703.9 (+/- 91.504)
Psychomotor Speed	147.1 (+/-30.824)	145.9 (+/- 40.752)	148.3 (+/- 18.487)
CPT Correct Responses	40 (+/- .0)	40 (+/- 0)	40 (+/- 0)
CPT Omission Errors	0.0000 (+/- .0)	0 (+/- 0)	0 (+/- 0)
CPT Commission Errors	0.3 (+/-.657)	0.1 (+/- 0.316)	0.5 (+/-.850)
CPT Choice RT Correct	439.5 (+/-46.136)	443.4 (+/-50.114)	435.6 (+/-44.142)
Stroop Simple RT	314.9 (+/-56.698)	326.6 (+/-59.627)	303.2 (+/-54.100)
Stroop Complex RT Correct	657.05 (+/-70.289)	676.9 (+/-65.643)	637.2 (+/-72.426)
Stroop Correct RT	740.25 (+/-108.879)	710.1 (+/-54.343)	770.4 (+/-141.610)
Stroop Commission Errors	1.5500 (+/-1.432)	0.7 (+/- 0.823)	2.4 (+/-1.430)
SA Correct Responses	46.5 (+/-14.125)	50.5 (+/-11.336)	42.5 (+/-16.036)
SA Errors	8.45 (+/-7.904)	6.3 (+/-6.183)	10.6 (+/-9.131)
SA Correct RT	1148.8 (+/-203.722)	1100.3 (+/-189.776)	1197.3 (+/-215.346)
FTT Right Taps Average	52.9 (+/-6.656)	52.9 (+/-7.490)	52.9 (+/-6.118)
FTT Left Taps Average	50.1 (+/-5.290)	50.3 (+/-6.634)	49.9 (+/-3.872)
Composite Memory	98.4 (+/-6.692)	101.7 (+/-7.660)	95.1 (+/-3.414)
Verbal Memory (VBM)	53.45 (+/-3.927)	55.3 (+/-3.466)	51.6 (+/-3.596)
Visual Memory (VIM)	44.95 (+/-5.073)	46.4 (+/-5.985)	43.5 (+/-3.719)
Reasoning	5.8 (+/-5.053)	7.1 (+/-3.928)	4.5 (+/-5.893)
Executive Functioning	38.05 (+/-21.537)	44.2 (+/-16.995)	31.9 (+/- 24.624)
Complex Attention	10.3 (+/-8.700)	7.1 (+/-6.607)	13.5 (+/-9.664)
Cognitive Flexibility	36.5 (+/-21.888)	43.5 (+/-17.367)	29.5 (+/-24.514)
VBM Correct Hits Immediate	12.95 (+/-1.761)	13.2 (+/-1.874)	12.7 (+/-1.703)
VBM Correct Passes Immediate	14.1 (+/-1.447)	14.4 (+/- 0.966)	13.8 (+/-1.813)
VBM Correct Hits Delayed	12.35 (+/-2.183)	13.5 (+/-1.43)	11.2 (+/-2.251)
VBM Correct Passes Delayed	14.05 (+/-1.432)	14.2 (+/-1.229)	13.9 (+/-1.663)
VIM Correct Hits Immediate	11.85 (+/-1.694)	12.1 (+/-1.595)	11.6 (+/-1.838)
VIM Correct Passes Immediate	11.5 (+/-2.013)	11.9 (+/-1.729)	11.1 (+/-2.283)
VIM Correct Hits Delayed	11.05 (+/-2.188)	11.8 (+/-2.658)	10.3 (+/-1.337)
VIM Correct Passes Delayed	10.55 (+/-2.328)	10.6 (+/-2.366)	10.5 (+/-2.415)
SDC Correct Responses	48.35 (+/-10.439)	51.0 (+/-9.638)	45.7 (+/-11.026)
SDC Errors	1.3 (+/-1.657)	1.2 (+/-1.229)	1.4 (+/-2.066)
NVRT Correct Responses	9.9 (+/-2.469)	10.5 (+/-1.900)	9.3 (+/-2.908)
NVRT Average Correct RT	5316.85 (+/-855.662)	5332.9 (+/-904.323)	5300.8 (+/-852.815)
NVRT Commission Errors	4.1 (+/-2.654)	3.4 (+/-2.119)	4.8 (+/-3.048)
NVRT Omission Errors	1.0 (+/-.858)	1.1 (+/-.876)	0.9000 (+/-.876)

3 Month Follow-Up CNS-VS and TMT Data

	All RPs	Piano RPs	Listener RPs
	Mean (+/- SD)	Mean (+/- SD)	Mean (+/- SD)
TMT Part A	25.506 (+/-5.814)	24.188(+/-5.682)	26.824 (+/-5.935
TMT Part B	58.6375 (+/-23.869)	52.004 (+/-18.385)	65.271 (+/- 27.694)
Reaction Time (RT)	685.4 (+/-85.447)	687.6 (+/-72.134)	683.2 (+/-100.993)
Psychomotor Speed	154.3 (+/-15.668)	156.3 (+/-15.784)	152.3 (+/-16.132)
CPT Correct Responses	40 (+/- .0)	40 (+/- 0)	40 (+/- 0)
CPT Omission Errors	0.0000 (+/- .0)	0 (+/- 0)	0 (+/- 0)
CPT Commission Errors	0.3158 (+.-.582)	0.2 (+/-.422)	0.4 (+/-.726)
CPT Choice RT Correct	443.47 (+/-49.207	445.7 (+/-52.572)	441.0 (+/-48.226)
Stroop Simple RT	316.35 (+/-43.732)	314.4 (+/-44.111)	318.3 (+/-45.641)
Stroop Complex RT Correct	628.5 (+/-62.785)	628.2 (+/-56.807)	628.8 (+/-71.377)
Stroop Correct RT	741.7 (+/-126.060)	746.3 (+/-108.547)	737.1 (+/-147.372)
Stroop Commission Errors	1.4 (+/-1.353)	1.1 (+/-.994)	1.7 (+/-1.636)
SA Correct Responses	49.25 (+/-11.951)	53.4 (+/-9.336)	45.1 (+/-13.270)
SA Errors	6.65 (+/-6.588)	4.5 (+/-5.359)	8.8 (+/-7.254)
SA Correct RT	1100.1 (+/-145.848)	1057.1 (+/-117.469)	1143.1 (+/-164.313)
FTT Right Taps Average	53.85 (+/-5.833)	53.6 (+/-6.222)	54.1 (+/-5.744)
FTT Left Taps Average	50.7 (+/-5.459)	51.3 (+/-6.684)	50.1 (+/-4.175)
Composite Memory	99.2 (+/-7.149)	101.5 (+/-8.502)	96.9 (+/-4.886)
Verbal Memory (VBM)	54.0 (+/-3.866)	54.8 (+/-4.263)	53.2 (+/-3.458)
Visual Memory (VIM)	45.2 (+/-4.384)	46.7 (+/-5.034)	43.7 (+/-3.199)
Reasoning	4.75 (+/-4.411)	6.6 (+/-2.757)	2.9 (+/-5.087)
Executive Functioning	42.6 (+/-18.112)	48.9 (+/-14.279)	36.3 (+/-20.011)
Complex Attention	7.85 (+/-7.162)	5.8 (+/-5.846)	9.9 (+/-8.048)
Cognitive Flexibility	41.2 (+/-18.472)	47.8 (+/-14.876)	34.6 (+/-20.057)
VBM Correct Hits Immediate	13.1 (+/-1.744)	13.0 (+/-2.309)	13.2 (+/-1.033)
VBM Correct Passes Immediate	14.4 (+/-.883)	14.4 (+/-.966)	14.4 (+/-.843)
VBM Correct Hits Delayed	12.4 (+/-2.186)	13.2 (+/-1.874)	11.6 (+/-2.271)
VBM Correct Passes Delayed	14.1 (+/-1.210)	14.2 (+/-.789)	14.0 (+/-1.563)
VIM Correct Hits Immediate	11.6 (+/-2.683)	12.0 (+/-3.162)	11.2 (+/-2.201)
VIM Correct Passes Immediate	11.4 (+/-2.280)	11.9 (+/-2.331)	10.9 (+/-2.234)
VIM Correct Hits Delayed	11.4 (+/-1.984)	11.5 (+/-2.461)	11.3 (+/-1.494)
VIM Correct Passes Delayed	10.8 (+/-2.505)	11.3 (+/-2.057)	10.3 (+/-2.908)
SDC Correct Responses	49.7 (+/-10.484)	51.4 (+/-9.789)	48.0 (+/-11.392)
SDC Errors	1.4 (+/-1.903)	1.3 (+/-1.252)	1.5 (+/-2.461)
NVRT Correct Responses	9.45 (+/-2.114)	10.4 (+/-1.350)	8.5 (+/-2.369)
NVRT Average Correct RT	4913.75 (+/-923.932)	5240.3 (+/-726.433)	4587.2 (+/-1018.567)
NVRT Commission Errors	4.7 (+/-2.364)	3.8 (+/-1.476)	5.6 (+/-2.797)
NVRT Omission Errors	0.85 (+/-.813)	0.8 (+/-.632)	0.9 (+/-.994)