Sensitive Period of Music Training and Late-Life Cognitive Reserve

--A Cross Sectional Comparison Between Older Adult Musicians

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Abstract

Healthy ageing is an essential topic for health care workers and professionals today. Music training is known for its benefits on cognition for all age groups. I studied the effect of music training on cognitive outcomes among older adult musicians based on their age of acquisition. I divided a sample of healthy older adults (N=31) who identified as having formal music training experience into two groups: early trained musicians (age of acquisition <= 7, mean = 5.8 years old, N = 13), and late trained musicians (age of acquisition >= eight years old, mean = 11.8 years old, N = 18). Participants completed a cognitive test battery examining their general cognitive functioning and a series of questionnaires asking about their life experience on many dimensions.

Independent t-tests showed that early trained musicians and late trained musicians did not significantly differ in their physical activity level, social activity level, or social support. Moreover, there were no group differences on test scores in the domains of executive functioning (D-KEFS Colour Word Interference Trial (CWIT) 3, Mann-Whitney U = 81, $p = 0.357$; D-KEFS CWIT Trial 4, Mann-Whitney U = 81.5, $p = .59$), verbal memory (CVLT short delay, $t = 1.29$, $p = .29$, or CVLT long delay, $t = 0.71$, $p = .48$), attention (Digit Span Backward, $t = 1.4$, $p = .17$, or Digit Span Sequence $t = -.13$, $p = 0.90$), or language (BNT, Mann-Whitney U = 84.5, $p = .43$). The result shows that the age of acquisition of music training may not impact long-term cognitive functioning in the current sample.

Introduction

With advanced technology and medical development, the population enjoys a longer life than decades ago. The number of people over 60 years old increased dramatically and will still grow in the following years (WHO, 2020). Healthy ageing is an essential topic for this generation since we have more older adults than decades ago. Dementia, as a disease associated with aging, has gained much attention from researchers and medical care workers. Dementia and other cognitive impairments have high medical bills and devasting effects on the individual and family members' lives. Anxiety, guilt, depression can all impact the immediate family members, especially spouses or partners who may also be an older adult. There can be many barriers to providing care for a loved one with dementia, including physical, financial, or other factors (Barrera-Caballero et al., 2021; Wulff et al., 2020).

The risks and protective factors for healthy ageing and prevention of cognitive impairments have been assessed by many researchers. One such factor is music training. Music training requires complex cooperation between perception and motor skills (Schlaug, 2015), showing positive cognitive effects in many areas of thinking and providing a better cognitive reserve on executive functioning, sensorimotor skills, rhythmic discrimination, and processing speed (Hyde et al, 2009; Strong & Mast, 2018; Strong & Midden, 2018). Therefore, music training could work as a protective factor for healthy ageing and help adults maintain healthy cognitive functioning in their late life.

Early sensory experiences, especially music training, have been studied by many researchers for potential cognitive outcomes. A sensitive period is believed to exist for music training, where children who trained at an early age may enjoy better cognitive outcomes and musical skills than those who start training late in life (White, 2013). Suppose a sensitive period exists for music training, early trained musicians may perform better, enjoy better executive functioning, better processing speed, and better cognitive reserve compared to their late trained peers.

One specific aspect of music training, age of acquisition of a musical instrument as a measure of a sensitive period, and its relationship with cognitive functioning in late life could be studied to give us a better idea of the long-term effect of early year music experience. In this study, I examine the relationship between age of acquisition and cognitive functioning among older musicians. The older adult musicians are divided into two groups: early learners and late learners, and I analysed differences in complex attention, memory, language, and executive functions between the two groups. I also controlled for the covariates of frequency of social activity, physical activity, and quantity of social support to ensure no group differences on these factors that can also impact cognitive functioning in late life.

Literature Review

Music training and the brain

The human brain has a capacity to adjust to the environment and respond to an outside stimulus; this adjustment is fundamental to human learning behavior, and the corresponding functional changes reflect the neuroplasticity of our nervous system. Neuroplasticity and related brain functioning change during music training draw our attention to what experiences might be important for brain development and how those changes happen. Research shows that music training is one of the most complex interactive behaviors humans have, requiring cooperation between perception and motor brain activities (Schlaug, 2015), which may cause structural brain changes in healthy human brains (Hyde, 2009). Instrument acquisition usually requires long-term training and commitment that have a long-lasting effect on people's brain, behavior, and cognitive functioning even if they stop playing music. Many studies support that the functional changes are related to music training, as musicians show different brain regional changes and tone responding changes specific to the instruments they trained with (Norton et al, 2005, Schlaug, 2005).

Music training is an intense sensory experience that impacts brain development. It requires the player to execute complex skills, including reading music, translating the information to precise motor movements, and monitoring auditory feedback throughout their performance (Schlaug, 2015). Much research has used longitudinal designs to examine if children with music training have higher cognitive functioning as a result of their music training. Research by Hyde et al. (2009) showed that structural brain change was observed in a group of children (avg. 6.3 yrs old) who received music training for 15 months. The brain changes were observed in the areas related to music training, shown in melodic/rhythmic discrimination test and right-hand motor performance. Another study by Schlaug (2005) also showed that after a year of music training, children show improvements in their fine motor skills and auditory discrimination skills compared to the control group. This is consistent with many other studies that musicians usually outperform non-musicians on fine motor skills, auditory-motor synchronization skills, executive functioning, and processing speed (Bailey, 2012; Hyde, 2009; Moreno, 2011; Schlaug, 2005; Strong & Mast, 2018; Strong & Midden, 2018).

Childhood is a sensitive stage for brain development (Schlaug, 2005) and is believed to enjoy more training-associated neuroplasticity compared to other stages in life. Many factors have been identified as influencing the brain structures through long-term learning behavior, the musician who started training at an early age builds more cognitive reserve throughout their life than a later trained musician (Schlaug, 2005, Bailey, 2012). Instrument acquisition during early age may better enhance cognitive functioning regardless of the education levels (Hanna-Pladdy, 2012). The brain functioning changes observed in adult musicians are environmentally induced, with those who begin training early in life having the greatest enlargement compared to other musicians and non-musicians (Norton et al, 2005).

Many researchers try to examine whether the benefits of music training could transfer to other high-level cognitive skills or untrained tasks. A far transfer effect is defined as a mastered skill that generalizes across domains that are less related and barely or not previously trained. For example, music training may cause a far transfer effect to mathematic ability (Portowitz, 2009). The researchers may be interested in the far transfer effect as we might be able to use music training in the treatment of various developmental disorders and other intervention programs related to cognitive aging. Unfortunately, many of those programs show mixed results on improving untrained tasks performance, and the magnitude of the effects tends to be small (Moreno, 2011). Hyde et al. (2009) show no far transfer effect in visual-spatial and verbal transfer outcomes in their study of administering 15 months of music training to school-age children. Other research by Dahlin et al. (2008), however, demonstrated a far transfer effect connected to the shared brain regions between music training and language learning, a link that has been shown on brain structures and cognitive levels, though the mechanisms of the connection remain unknown. In another study by Moreno (2011), training in music listening skills could benefit executive functioning and verbal abilities as a far transfer effect. Portowitz (2009) also studied how music training may relate to spatial intelligence and abstract reasoning, which may benefit mathematics learning and other academic performance. His study shows music training benefits the students in their problem solving and general learning skills. Some other studies reported that music training might enhance verbal memories, general IQ, and language comprehension (Moreno et al, 2009; Norton, 2005), this may be a result of shared brain regions among different cognitive behaviors. Furthermore, many of the music training programs happen under artificial settings or within laboratories, which lack abilities to apply real-life situations or promise long-term behavioral changes.

The length of playing and intensity of music training (Hyde, 2009) may positively help musicians' performance on other cognitive tasks, defined as a far transfer effect (Gooding, 2014[JS4], Hanna-Pladdy & Mackay 2011, Moreno, 2011, Schlaug, 2005). The musicians experience a brain structure change corresponding to the intensity of their music training experiences compared to non-musicians (Norton et al, 2005). This is also shown in Schlaug's 2005 study, that on an average of four years of music training, the predicted effects of motor skills and auditory discrimination is stronger than the groups who received only one year of music training, and the far transfer effects also started to emerge in some related domains.

It is not possible to determine whether musicians are born with pre-existing musical talents or biological traits that makes them decide to continue playing music after the training started (Hyde, 2009), however, most studies show that musicians benefit from cognitive and behavioral change after short- or long-term music training. In Norton's study (2005), he was interested in whether the fictional and structural differences seen in musicians result from the adaptation of strong environmental factors when they receive intense music training or existed before the musicians started formal training. While no pre-training differences were found between children who chose to participate in music training and those who decided not to, yet there were differences found after music training. Thus, Norton concluded that the brain differences seen in musicians are likely to be the result of music training, rather than pre-existing differences.

Music training and sensitive periods

Penhune (2020) states that "a sensitive period is a window in development when specific experience has particularly potent effects on brain plasticity, and thus long-term effects on structure and function." Therefore, intense music training during a sensitive period may have a long-lasting effect on human development (White, 2013). A related concept, the critical period, is often used interchangeably with the sensitive period. A critical period is when the behavior or neural development only occurs as exposure to specific experience (Penhune, 2020). In contrast to the critical period, if a skill is not acquired during a sensitive period, it is still possible to acquire it outside of a sensitive period without impacting people's overall cognitive development. Some examples include second language acquisition, learning an instrument, or playing chess: all skills that can be learned at any time in the lifespan (Penquin, 2020). Although the most widespread example of a sensitive period is conducted on language acquisition (especially second language acquisition), finding out whether music training is time-sensitive can help us understand if it is developmentally tuned and can be acquired more easily (Newport, 2001) or provide better protection on cognitive functioning during a certain stage of life.

Music training and language acquisition largely rely on auditory processing (White, 2013), while much formal music training happens early in life, it provides the researchers the opportunities to study how brain capacity allows people to learn and change their behavior based on environmental stimulus, and the effect of music training during a sensitive period. The nature of music training that requires a large amount of practice across a long period of time also promotes the neuroplasticity of human brains. Many examples of world-famous musicians suggest that early trained musicians may experience better skills acquisition later into adulthood, such as Mozart, who could perform on the piano professionally at the age of 5 (Penhune, 2020); Beethoven started the music training before the age of 8 (Watanabe, 2006).

Many researchers believes that an early trained musician experiences more brain plasticity. It helps children develop an absolute or perfect pitch, defined as recognizing a pitch without reference to external pitches. The operational definition for the ability of absolute pitch (AP) is not evident among researchers, while some believe the absolute pitch only requires the musician to recognize the pitch, others believe it is essential for musicians to produce the correct pitches without reference or using a tone generator. Nevertheless, the relationship between the age of receiving music training and acquisition of AP has gained much attention since mid 20 century. Despite the advanced understanding of human auditory system development, the underlying mechanisms of pitch discrimination remain unclear. Research by Baharloo et al. (1998) suggested that early musical training is essential for the development of AP, as most of their participants (78% of 92 musicians) who self-reported having AP started their training before six years old. In another survey, the rates of self-reported AP are 40% among the musicians who started their training before four years old, but only 3% in those who started after nine years old (Vanzella et al,, 2010). Baharloo et al. (1998) hypothesize the phenomenon is a result of a critical period, which if not start training early in life, AP will not develop. Otherwise, there may be a genetic component. AP could also be inherited when more than one family member or relative has AP; a child may be more likely to develop a particular phenotype that contributes to AP.

Research by Vanzella et al. (2010) was explicitly interested in musicians' performance on pitch discrimination among different timbres, included human voice. The result shows that the AP possessors had difficulty distinguishing vocal pitches compared to non-vocal tones (such as piano). The note naming ability is generally better among musicians who started their training before the age of 7 and received piano lessons as the primary instrument.

A clear cut-off age is used in many research studies to identify the age of the sensitive period ended, so as to compare the cognitive functioning difference between early trained musicians and late trained musicians. As early as 1995, Schlaug, Jancke, Huang, Staiger, and Steinmetz found that the musicians who start training before the age of 7 enjoy enlargement in corpus callosum compared to both non-musicians and late trained musicians. Penhune (2020) conducted research comparing the musical ability and brain functioning in early and late trained musicians, using seven years old as a cut-off. When matching for years of experience, years of formal training, and hours of current practice, the early trained musician performed better on rhythm synchronization and melody discrimination. In the second stage of Penhune's (2020) study, he controlled for working memory, global cognitive function, and socioeconomic status, the result shows that the early trained musician still outperforms on melody discrimination tasks, illustrated that basic pitch ability is impacted by onset age of music training. Research by Wan (2010) found that the musicians who started training before seven years old enjoy a better enlargement in their motor brain regions and corpus callosum (responsible for executive functioning). Other research by Steele et. al (2013) used seven years old as a cut-off age to distinguish early and late trained musicians and found a difference in white matter structure and sensorimotor synchronization performance. Early trained musicians show a better sensorimotor synchronization ability.

Other research on the sensitive period of music training provides some evidence for how early music training may impact auditory development, visual development, and somatosensory experience (Steele et al, 2013). Bailey (2012) matched previous musical experience, including years of formal training, current hours of play, and playing experience. The early trained musician showed a better sensorimotor synchronization skill compared to the late trained musicians. At the same time, non-musicians ' rhythm synchronization ability is inferior to both early trained and late trained musicians. When the three groups did not significantly differ in all the cognitive tasks they performed, Bailey (2012) concluded that the distinguished sensorimotor ability was more likely due to the age of started music training. Watanabe et al. (2006) also showed that early trained musicians perform better novel rhythmic tapping task and response synchronization compared to their peers who have matched with experience and training. An early start in music training provides a better chance for musicians to gain motor skills that they may benefit in later performance, the changes on their motor performance and ability of synchronization usually have a long last effect in their performance.

Many researchers believe that the onset age of music training and the intensity of music training (years of playing, hours of practice per week) determine the cognitive changes related to the training. Many other factors can be addressed that might impact the neurological development of musicians, such as lifestyles, education, socioeconomic status, diet, and more.

Cognitive aging

Aging is a process represented by age-related changes in many domains, such as perception, motor ability, cognition. Although people connect cognitive impairment to dementia or other common cognitive disorder, healthy non-demented older adults also experience a change in their cognitive processing, memory, reasoning, and other brain functioning in the aging process. With the development of technology and neuroimaging scans such as MRI, researchers revealed the underlying brain changes of cognitive impairment. In a review by Raz (2006), much literature indicates that brain shrinkage happens with the aging process and only happens on certain brain regions at different rates. Brain shrinkage is not random nor uniform, and the brain structure change impacts cognition as the brain volume links to the performance in many domains.

The "disconnected brain" theory views cognitive aging as relates to the efficiency of connections between different brain regions (Fjell, 2017). Reducing connectivity during the aging process impacts processing speed and executive functioning. Research by Feijj et. al (2017) used the Stroop color-word interference test (CWIT) to assess the executive function change during the aging process. They demonstrated that the two tasks that show an age-related change are inhibition and switching costs tasks, and both are related to reduced connectivity in brain structure. This longitudinal study provided evidence for the 'disconnected brain' theory by accessing the brain structure change and the executive function of the participants from different age groups.

In research by Hoogendam et al. (2014), age had a clear effect on general cognition functions in populations over 45 years old. Among several tasks the participants completed in this research, fine motor skills, processing speed, and visuospatial ability are largely impacted by participants' age. Age-related change was also seen in motor skills and executive functions (Bugos, 2019). The neuromuscular system might experience a reduction that contributes to reduced attention span and motor skills, causing challenges for older adults to develop new skills in late life. An intervention targets the bimanual coordination tasks, in return, may delay the degeneration of the neuromuscular system in older adults and help reduce their risks of age-related cognitive change. Bugos et al. (2007) show that the aging adults who receive a 6-months piano training program improve executive functions and working memories compared to a control group. Many cognitive benefits such as perceptual speed and visual scanning are still maintained after a three-month delay period.

Reducing activity level due to retirement may reduce brain and cognitive functioning and impact the learning capacities and memory of older adults. Therefore, appropriate cognitive training or activity around retirement time may reduce the risk of dementia among older adults (Wan, 2010). Given that brain plasticity is possible across the life span, the power of intense music training on brain functioning is investigated by many researchers on whether musicians enjoy better cognition during the aging process. Many tasks that require fine motor skills and motor coordination may impact cognitive performance. Kim et al. (2017) showed a correlation between the completion of electric drum tasks and cognitive tasks examining executive functions among older adults. An experience-dependent change in the human brain has been observed in many professional musicians, which might be a result of intense music training, that musicians devote several hours in practice instrument to develop a complex sensorimotor skill.

Bugos (2019) investigated the effects and cognition/fine motor skills outcomes when healthy older adults attend to musical tasks that require bimanual coordination, compared to the healthy older adults who attend to non-motor musical intervention, such as listening to music. The purpose of her research was to examine the factor that decides the cognitive outcomes of music training, especially how bimanual coordination skills relate to the participants' executive functions outcome. The results showed that the participants who receive music training involving instrument practice (either piano or mallet) had significant improvement in visual scanning and working memory. The participants who received piano training also showed an increased in processing speed.

Some non-pitch instruments, such as drums, require gross motor skills that don't associate with accurate muscle control and melody discrimination skills, but may still contribute to positive health-related outcomes. Sung et al. (2012) research participants reported significantly reduced anxiety levels after a 6-week drumming intervention program. Another group of participants who received a six-week West African drumming class also reported a higher quality of life (Bugos, 2019).

Despite the positive outcome of participating in an intervention program during late life, many researchers are also curious about whether the enhanced cognitive functioning related to music training has a long-last effect, into the late life of musicians. Hanna-Pladdy and MacKay (2011) evaluated the cognitive differences between non-musicians, low activity musicians, and high activity musicians to reveal cognitive reserve in late life. The result demonstrated significant effects on many cognitive measures, including naming, nonverbal memory recall, visuomotor speed, visuomotor sequencing, and cognitive flexibility. While the age of acquisition is similar for both low and high activity musicians, the years of total playing shows a correlation with cognitive functioning, suggests that the length of musical participation may impact cognitive function in advanced age. In another study by Gooding et al. (2014), the musicians who self-reported longer music training experience, had improved semantic and episodic memory in late life. This finding matches other research on the relationship between length of training and cognitive reserve, support that the cognitive improvement may be a result of music training.

Current Study

My study is interested in how the age of acquisition of music training may impact cognitive aging among older adults. The primary participants of this research are older adults with some music experience or self-identified as musicians. I collected data in two parts. The first part included questionnaires that allows older adults to report their music experience, lifestyle, socioeconomic status (SES), education background, and social and physical activity level. The second part included several cognitive tests that monitor participants' cognitive functioning yearly. The current project only uses a cross-sectional design with first-year data of a longitudinal study. I divided the musicians (N=31) with at least some music training experience into two groups, early trained musicians (age <= 7, N = 13) and late trained musicians (age >= 8, N = 18). By comparing the cognitive functioning of two groups of musicians with early or late age of acquisition, I can investigate how the age of acquisition of a musical instrument may impact older musicians' cognitive functioning during the aging process.

Method

Participants & Procedures

The current study was approved by the University of Prince Edward Research Ethics Board. The older adults (Age > 60 years, Mean = 70.5 years old) who self-identified as musicians (N=31) were recruited from the community and asked to complete the cognitive battery and questionnaires every year, for a total of three years. My study uses data from Year 1. Posters went to libraries and senior activity centers and an email was sent to the UPEI Senior’s College to recruit older adults interested in music training and how it relates to their cognitive functioning. Participants were screened for age (>60), being a resident of PEI, and excluded for any history of diagnosed neurologic disease (Parkinson's, stroke, dementia, brain tumors). After screening, we contacted the participants to arrange an appointment for their first-time testing. One researcher administers the testing, and the test including several different questionnaires and cognitive tests. Both cognitive battery and questionnaires could be completed in older adults' homes or the research lab at UPEI. First-time testing usually lasted 3-4 hours. Participation was fully voluntary, and the participants could withdraw from the study at any time of their participation. After completing the questionnaire and the cognitive battery, each participant was entered into a raffle to win one of ten $100 coupons.

Materials

A cognitive battery was designed to assess all major cognitive domains, and some questionnaires were used in this research for data collection. The researcher administered all tests and questionnaires with the participant on pencil and paper.

Executive functioning

The color world interference trials are an executive function task that requires the participants to read four different lists; the first and second lists are simply naming the color of the square and then reading color words as written, respectively. The third list requires the participant to read the color of the ink rather than the word, and the final list requires a more complex inhibitory/switching component that asks the participants to switch between naming the ink color or reading the word depending on whether the word is in a box (D-KEFS; Delis et al., 2004).

Rey Complex Figure Test (RCFT) examines executive memory. RCFT requires the participants to copy down a complex figure that includes several different sections, then 3-

minutes later freely recall the figure from memory. After 20-30 minutes, they are asked to do a delayed recall of the figure from their memory (RCFT; Fastenau et al., 1999).

Memory

The California Verbal Learning Test (CVLT-3) measured verbal learning, verbal memory, and delay recall. A list of words was read to the participants for learning and free recall. The learning tasks includes repeating a list for five trials. When 5 trails are finished, one distractor trial is introduced followed by a free recall of distractor. Next, there is a free and cued short-delay recall of the initial word list that was read 5 times. After 20-30 minutes, the participants are again asked to recall the first list of the words freely, and with cues.

WMS-IV Logical Memory Scale is a task to examine auditory memory for two short stories (WMS LM I & II; Wechsler, 2008). The participants are asked to recall the story immediately and after a delay. The first story is read two times, followed by an immediate recall, while the second story is read once. After 20-30 minutes, the participants are asked for delayed recall for both stories.

Attention

I used the digit span (DS) task from Wechsler Adult Intelligence Scale (WAIS-IV) to examine the basic and complex attention skills of the participants (Wechsler et al., 2008). In this task, the participants must repeat a number sequence that grows longer each time they get it correct. This task included forward condition, backward condition, and sequenced condition that requiring participants to repeat the number sequence from the lowest to the highest.

Language

The Boston Naming Test (BNT) includes presenting pictures of items for the participants to name. The short version that has 30 items are used in this research to examine participants' language skill (Ferraro & Lowell, 2010). During the test, the participants could use their time wisely, and different types of cues (semantic cues; phonemic cues) may be provided if they couldn't name the item.

Physical activity

The Physical Activity Scale for the Elderly (PASE) is a self-report questionnaire used in this research to obtain information about level of physical activity among older adults (PASE; Washburn et al., 1993). The PASE includes 10 questions that ask the frequency of engaging in different activities, how many hours per day the participants spend in different activities, and the specific activities the participants engage in. An example of a question on the PASE is, "Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV, or doing handcrafts?" The PASE has been found to have good reliability (Cronbach's alpha = 0.73, Loland, 2002).

Social Activity Level

The California Older Persons Pleasant Events Scale (COPPES) is a self-report measure that originally includes over 60 enjoyable activities, and the participants are required to report how often they engage in each activity and how enjoyable the activity is (COPPES; Rider et al., 2004). This study abbreviated the COPPES to 32 items. The full version COPPES is reliable (Cronbach alpha coefficient = .93 on the Frequency Domain, and .97 on the Pleasure Domain; Rider et al. 2004) and one example item includes "Being with friends."

Social Support

The 12 item Interpersonal Support Evaluation List (ISEL) is a self-report measure in which participants select an answer from a 4-point scale from 1-definitely false to 4-definitely true (ISEL12, Cohen & Hoberman, 1983). A higher score indicates poor interpersonal support. The ISEL is found reliable (Cronbach's alpha coefficient = 0.77, Cohen and Hoberman, 1983). An example item is, "I feel that there is no one I can share my most private worries and fears with."

Data analysis

The research question asks whether the age of acquisition of primary instruments impacts older musicians' cognitive functioning. The older adult musicians were divided into early trained musicians, who started their primary instrument before or at seven years old. The late trained musicians were musicians who started at eight years old or later.

I used independent t-tests to examine whether it is a significant difference between groups on the physical activity and social activity level and social support. Specifically, I ran independent sample t-tests for social support (ISEL frequency of social activity (COPPES), and physical activity level (PASE), as they may impact cognitive functioning during late life. After checking the assumptions, the ISEL score violated the homogeneity assumptions, so I ran a Welch's t-test instead of a Student's t-test.

After examining all the possible covariates above, I ran independent t-tests for all the other cognitive tests related to early music experience and age of acquisition, including DKEFS color world interference and RCFT for executive functioning, CVLT-3 and LM for memory, Digit Span for attention, and Boston naming for language. After checking the assumptions, Boston naming, color word trials 3 and 4 violated the normality assumption, so I ran the Mann-Whitney U instead of the Student's t-test. The statistics for all dependent variables can be found in Appendix D.

Results

Thirty-one participants were included in the analysis, with 13 of them being early acquisition musicians (acquisition of primary instrument before seven years old) and 18 late acquisition musicians (acquisition of primary instrument after eight years old). I didn't match the participants for years of formal training, years of daily practice, and hours per week playing as the sample size was comparably small. The demographic statistics are shown at the end of the paper in Appendix A. Briefly, the sample consisted of 13 men (6 in the early trained musicians) and 18 women (7 in the early trained musicians), with an average age of 70.6 years old. Overall, the sample was relatively highly education (27 out of 31 participants have obtained a post secondary degree or higher education). Otherwise, all the participants in this sample retired from their job.

There was a significant difference between the two groups of musicians on the age of acquisition (Whitney U = 0.00, $p < 0.01$, rank biserial correlation = 1), early trained musicians had a group mean age of 5.8 years old, and the late trained musicians had a group mean age of 11.8 years old.

There were no significant differences between early trained musicians and late trained musicians in any given control variables, including social support (Welch's T, t (26.4) = 1.5, p = .14, MD = 2.89, d = 0.53), social activity level (t (25) = 1.63, p = .11, MD = 5.30, d=0.64), and physical activity level ($t(29) = -0.71$, $p = .48$, MD = -.69, $d = -.26$). See the table in Appendix B for grouping variables, Appendix C for covariates, Appendix D for dependent variables, and Appendix E for Group Descriptives for dependent variables.

Executive functioning

For executive functioning, no group difference were observed between early trained musicians and late trained musicians on D-KEFS Color-Word Interference Trial 3 (Mann-Whitney U = 81, $p = 0.357$, Rank biserial correlation = 0.21), or D-KEFS Color-Word Interference Trial 4 (Mann-Whitney U = 81.5, $p = .59$, Rank biserial correlation = 0.12). I also compared group differences on RCFT as a measure of executive functioning. RCFT delayed recall showed no group difference between two groups of musicians, $t\ (27) = 0.132$, $p = .90$, $d = 0.05$.

Memory

No difference was observed between the groups on CVLT short delay ($t\ (24) = 1.29$, $p =.29$, $d = .51$, or CVLT long delay ($t\ (24) = 0.71$, $p = .48$, $d = 0.28$). Logical memory scale II shows no group difference, $t\ (24) = -0.85$, $p = .40$, $d = .34$. However, the CVLT-short delay had a medium effect size, indicating a finding of medium importance despite the non-significant *p*-value.

Attention

There were no group difference on Digit Span Backward ($t\ (27) = 1.4$, $p = .17$, $d = 0.53$), or Digit Span Sequence ($t(27) = -.13$, $p = 0.90$, $d = -\ 0.05$. Again, the effect size of digit span backward indicates a medium effect, suggesting findings of importance without reaching the threshold of statistical significance.

Language

Boston Naming Test showed no significant group difference (Mann-Whitney U = 84.5, $p = .43$, Rank biserial correlation = 0.17).

Discussion

This study examined executive functioning, memory, attention, and language differences between older adult musicians who started playing their primary musical instrument early (mean age of acquisition = 5.77) or later in childhood (mean age of acquisition = 11.8). There was a significant difference between two groups' acquisition age, so I could compare the cognitive functioning between the groups based on their age of acquisition.

No significant difference was observed between the two groups on any covariates: physical activity, social activity, or social support. Wan (2010) explained that the reduced activity level might be related to reduced cognitive functioning during late life. Higher levels of physical activity or social activity may benefit cognitive functioning and decrease the risk of dementia among older adults. Middle aged to older adults with a high social support level also demonstrates a higher cognitive function (Oremus et al., 2019). Therefore, no significant difference in physical activity level, social activity level, and social support mean these covariates likely could not account for participants' cognitive functioning in the current study. Otherwise, the early trained musicians has a higher mean score on boston naming for language, CVLT short delay and long delay for verbal memory, color word trial 3 for executive functioning, Digit Span backward for complex attention, and RCFT for visual memory. This means early trained musicians might enjoy more cognitive improvement compare to late trained musicians, although not statistically significant.

Moreover, no significant difference was observed on any cognitive tests for executive functioning, memory, attention, and language. This result was not expected given my review of the literature and hypothesis that different ages of acquisition might impact cognitive aging and cognitive functioning differently. Research shows that after the age of 45, general cognition shows an age-related change in the population, and fine motor skills, processing speed, and visuospatial ability are all impacted by normal aging (Hoogendam et al. 2014). Much research indicates that musicians who received music training earlier in life enjoy better cognitive reserve due to better age-related neuroplasticity (Schlaug, 2005). And previous studies have found that intensive music training during sensitive periods enhances cognitive functioning during the ageing process (White, 2013). The ability to develop a new skill, such as instrument acquisition, at an early age might be stronger and provides more cognitive protection against age-related cognitive change. But the data in my research didn't indicate such effects, and none of the cognitive measures show a significant group difference.

The fact that many of the cognitive tests did not show significantly different results could have several different reasons, 1) age of acquisition only impacts the music-related executive functioning, such as rhythm synchronization and sensorimotor skills, which were not examined in this research, 2) the life experience of older adults is complicated by the decades of life that occurred since acquiring an instrument so that early music training experience may not be able to predict cognitive outcome in late ages, 3) due to a smaller than expected sample size, the power of the research is lower than expected, so I am not able to detect the differences.

Much research shows intensive music training on tonal instruments improves musicians' melodic discrimination and fine motor skills (Bailey, 2012, Hyde et al, 2009, Penhune 2020, Schlaug 2005, Steele et al, 2013, Watanabe et al. 2006), as they are more directly related to play an instrument. I did not observe any group differences in older adults' complex attention, executive functioning, memory, and language skills in my research. As I discussed earlier, a far transfer effect of music training is defined as the skills that can be generalized to another domain less related to previous training. For example, music training does not just improve the fine motor skills used in playing piano but improves general cognition, IQ, and language skill (Moreno et al., 2009; Norton, 2005, Portowitz, 2009). The existence of the far transfer effect in music training is controversial, and research does not show a consistent result on brain regions shared with music training, resulting in a far transfer effect. So, the early acquisition of music training may not have a substantial impact on general cognition to detect any far transfer effect years after, and music acquisition experience doesn't strongly impact general executive functioning, memory, attention, and language in late life. As the musicians gain more music experience during their life, the differences made by the age of acquisition could vanish, based on their years of formal training, hours of practice, and other factors. The two musician groups I used showed a significant difference in age of acquisition, but no significant difference in the general music experiences.

Another hypothesis is that the life experiences of older adult musicians are so complicated that I couldn't determine what experiences impacted their cognitive functioning. In my research, I encountered physical activity, social activity, and social support as covariates that impact cognitive ageing. Compared to Penhune's (2020) research, he matched the years of musical experience, years of formal training, hours of current practice, working memory, cognitive function, socioeconomic status, and showed that early trained musicians outperform late trained musicians on many skills, there are more factors could be considered in my research design. I used the standardized score for many cognitive tests to ensure the participants were matched for education using the normed scores. Still, it could be possible to figure out a better way to engage the covariates directly in the data analysis. Other major life events could result in different cognitive outcomes, for example, history of head injury or diet and other health factors across the life. It is challenging for me to put an older adult's life into numbers and make sure I am representing their life experience. It's possible any links between an early life event like music training and late-life cognition cannot be established very easily because so many covariates occur in the decades in between.

Another hypothesis regarding the null findings is the power. My power is so much lower than expected, so there is a chance I made some type 2 errors and didn't detect the significant differences between the two groups, even though they exist. Using G*power, my power was calculated to be around .20, where generally the goal power is .80. Those numbers suggest the study is significantly underpowered to detect any differences. Additional evidence for Type 2 error is seen in the effect sizes. In CVLT short delay free recall, for example, I got a *p*-value of 0.21 and effect size $d = 0.51$, this is a medium effect size, suggesting some importance in the findings, but without statistically significant differences. Similarly, in Digit Span Backward, I got a $p = 0.17$, effect size $d = 0.53$, also a medium effect size. Given the low power I have in this research, those two cognitive tests might have failed to reach the threshold of significance (.05) as I have such a high chance (over 70%) of making Type 2 errors.

Limitations and future directions

Few researchers would put the sensitive period and older adults together since the sensitive period is exclusive to children. This design is newer, and I think it would be helpful in exploring the long-term cognitive outcome of early age music training by examining older adult musicians. The disadvantage of the design is I didn't use a control group to compare with the two groups of musicians, even if the score of the cognitive battery is standardized, it is still unclear what is the baseline of older adults' cognitive functioning.

Otherwise, many other covariates could be considered and may be included in the analysis. Finally, a larger sample size (30-50 in each group rather than in total sample size) would boost the power of the study to detect differences. I only had 31 participants in total who satisfied my selection criteria. The power of this research is shown to be extremely low, and it is very hard to detect any significant differences if they exist.

Conclusions

Older adults' life experience has gained attention from psychologists, medical care workers, professionals, and family members. It is essential to realize the risk factors and protective factors on older adults' cognitive functioning. Early music training may promote neuroplasticity and cognitive development, the sensitive period of music training and its effect is still unclear. Moreover, examining the relationship between early music training experience and late-life cognitive functioning is complex, particularly when considering a potential sensitive period of music training.

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Appendices

Appendix A: Demographics

	EARLY ACQUISITION (<7 YEARS OLD, N=13)	**LATE ACQUISITION (8 YEARS OLD +, N=18)**
GENDER		
MALE	6	7
FEMALE	7	11
RACE		
WHITE	13	17
MORE THAN ONE RACE	0	1
AGE	63-76, M=71.9, SD=4.27	61-84, M=69.6, SD=6.21
YEARS OF EDUCATION	15-20, M=17.3, SD=1.6	12-24, M=17.6, SD=3.7
HIGHEST DEGREE		
HIGH SCHOOL	0	4
BACHELORS	10	7
MASTERS	1	4
DOCTORAL	1	2
MARITAL STATUS		
SINGLE	0	3
DIVORCED/SEPERATED	3	2
WIDOW(ER)	0	2
MARRIED	10	10
COMMON LAW	0	1
EMPLOYMENT STATUS		
RETIRED	13 (100%)	18 (100%)
EMPLOYEED	0	0
AGE OF ACQUISITION	2-7, M = 5.8 years old	8-20, M = 11.8 years old
YEARS OF FORMAL TRAINING		
0-1 YEARS	1	3
1-3 YEARS	1	6
4-5 YEARS	3	5
6-10 YEARS	6	1
10+ YEARS	1	2
YEARS OF REGULAR DAILY PRACTICE		
0-1 YEARS	1	2
1-3 YEARS	2	2
4-5 YEARS	1	2
6-10 YEARS	2	0
10+ YEARS	7	11
HOURS PER WEEK PLAYING AFTER 60 YEARS OLD	Missing = 4, 0-70, M=14, SD = 22.2	Missing = 2, 0-104, M=12.8, SD = 24.9

Appendix B: independent t-test for grouping variable and assumptions

Independent Samples T-Test

		Statistic	*p*	Mean difference	SE difference		Effect Size
MQ18	Mann-Whitney U	0.00	< .001	-5.00		Rank biserial correlation	1.00

Normality Test (Shapiro-Wilk)

	W	*p*
MQ18	0.842	< .001

Homogeneity of Variances Test (Levene's)

	F	df	df2	*p*
MQ18	4.94	1	29	0.034

Note: MQ18 = Age of acquisition of primary instrument

Appendix C: T-test for covariate and assumptions

Independent sample t-test				
	Statistic		df	*p*
Total Social Frequency	Student's t	1.636	25.0	0.114
ISEL total	Welch's t	1.521	26.4	0.140
Physical activity total	Student's t	-0.711	29.0	0.483

Normality Test (Shapiro-Wilk)

	W	***p***
TotSocialFreq	0.955	0.283
ISELTot	0.942	0.101
PhysActTotal	0.936	0.063

Homogeneity of Variances Test (Levene's)

	F	**df**	**df2**	***p***
TotSocialFreq	0.645	1	25	0.430
ISELTot	5.340	1	28	0.028
PhysActTotal	0.503	1	29	0.484

Note: TotSocialFreq = Frequency of Social Activity (COPPES); ISELTot = perceived social support (ISEL); PhyActTotal – Physical Activity Level (PASE)

Appendix D: T test for dependent variables and assumptions

Independent Samples T-Test

		Statistic	df	*p*		Effect Size
BNT_z	Mann-Whitney U	84.5		0.431	Rank biserial correlation	0.1716
CVLT_SDFR_ss +	Student's t	1.292	24.0	0.209	Cohen's d	0.5127
CVLT_LDFR_ss +	Student's t	0.710	24.0	0.484	Cohen's d	0.2819
CW3_ss +	Mann-Whitney U	81.0		0.357	Rank biserial correlation	0.2059
CW4_ss +	Mann-Whitney U	89.5		0.589	Rank biserial correlation	0.1225
LMII_ss +	Student's t	-0.854	24.0	0.401	Cohen's d	-0.3391
DSB_ss +	Student's t	1.400	27.0	0.173	Cohen's d	0.5278
DSS_ss +	Student's t	-0.125	27.0	0.901	Cohen's d	-0.0472
RCFTDelay_t +	Student's t	0.132	27.0	0.896	Cohen's d	0.0497

Normality Test (Shapiro-Wilk)

	W	*p*
BNT_z	0.914	0.022
CVLT_SDFR_ss	0.936	0.109
CVLT_LDFR_ss	0.963	0.459
CW3_ss	0.899	0.009
CW4_ss	0.877	0.003
LMII_ss	0.924	0.055
DSB_ss	0.947	0.156
DSS_ss	0.971	0.582
RCFTDelay_t	0.952	0.209

Homogeneity of Variances Test (Levene's)

	F	df	df2	*p*
BNT_z	4.19561	1	27	0.050
CVLT_SDFR_ss	0.62266	1	24	0.438

Homogeneity of Variances Test (Levene's)

	F	df	df2	*p*
CVLT_LDFR_ss	0.00237	1	24	0.962
CW3_ss	0.11303	1	27	0.739
CW4_ss	0.32232	1	27	0.575
LMII_ss	2.68443	1	24	0.114
DSB_ss	0.64718	1	27	0.428
DSS_ss	0.25481	1	27	0.618
RCFTDelay_t	0.00894	1	27	0.925

Note: BNT_z = Boston Naming Test z-score; CVLT_SDFR_ss = California Verbal Learning Test-3 short delay free recall – scaled score; CVLT_LDFR_ss = California Verbal Learning Test-3 long delay free recall – scaled score; CW3_ss = D-KEFS Color-Word Interference Trail 3 – scaled score; CW4_ss = D-KEFS Color-Word Interference Trail 4 – scaled score; LMII_ss = WMS-IV Logical Memory Scale II - scaled score; DSB_ss = Digit Span Backward – scaled score; DSS_ss = Digit Span Sequence – scaled score; RCFTDelay_t = Rey Complex Figure Test Delay Recall – t-score

Appendix E: Group Descriptives for Dependent Variables

Group Descriptives

	Group	N	Mean	Median	SD	SE
BNT_z	7 and younger	12	1.03	1.08	0.702	0.203
	8 and older	17	0.754	1.08	0.875	0.212
CVLT_SDFR_ss	7 and younger	11	13.55	14.00	2.505	0.755
	8 and older	15	12.067	12.00	3.127	0.808
CVLT_LDFR_ss	7 and younger	11	12.82	14.00	2.676	0.807
	8 and older	15	12.067	12.00	2.658	0.686
CW3_ss	7 and younger	12	12.67	12.50	2.146	0.620
	8 and older	17	11.588	12.00	2.476	0.601
CW4_ss	7 and younger	12	12.00	12.00	2.216	0.640
	8 and older	17	12.235	13.00	2.488	0.603
LMII_ss	7 and younger	11	11.45	11.00	3.236	0.976
	8 and older	15	12.267	12.00	1.534	0.396
DSB_ss	7 and younger	12	11.92	11.00	2.778	0.802
	8 and older	17	10.588	10.00	2.320	0.563
DSS_ss	7 and younger	12	11.75	11.50	2.958	0.854
	8 and older	17	11.882	12.00	2.690	0.652
RCFTDelay_t	7 and younger	12	60.92	62.00	12.340	3.562
	8 and older	17	60.294	61.00	12.638	3.065