HHS Public Access
Author manuscript
Neuropsychology. Author manuscript; available in PMC 2015 March 10.

Published in final edited form as:
Neuropsychology. 2011 May ; 25(3): 378–386. doi:10.1037/a0021895.

The Relation Between Instrumental Musical Activity and Cognitive Aging

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Abstract

Objective—Intensive repetitive musical practice can lead to bilateral cortical reorganization. However, whether musical sensorimotor and cognitive abilities transfer to nonmusical cognitive abilities that are maintained throughout the life span is unclear. In an attempt to identify modifiable lifestyle factors that may potentially enhance successful aging, we evaluated the association between musical instrumental participation and cognitive aging.

Method—Seventy older healthy adults (ages 60–83) varying in musical activity completed a comprehensive neuropsychological battery. The groups (nonmusicians, low and high activity musicians) were matched on age, education, history of physical exercise, while musicians were matched on age of instrumental acquisition and formal years of musical training. Musicians were classified in the low (1–9 years) or high (>10 years) activity group based on years of musical experience throughout their life span.

Results—The results of this preliminary study revealed that participants with at least 10 years of musical experience (high activity musicians) had better performance in nonverbal memory (η^2 = .106), naming (η^2 = .103), and executive processes (η^2 = .131) in advanced age relative to nonmusicians. Several regression analyses evaluated how years of musical activity, age of acquisition, type of musical training, and other variables predicted cognitive performance.

Conclusions—These correlational results suggest a strong predictive effect of high musical activity throughout the life span on preserved cognitive functioning in advanced age. A discussion of how musical participation may enhance cognitive aging is provided along with other alternative explanations.

Keywords

music; music cognition; cognitive aging; nonverbal memory

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The authors report no conflicts of interest.

There is increasing interest in identification of lifestyle modifiable factors or interventions that may enhance the cognitive vitality of older adults and possibly delay the onset of dementia like Alzheimer's disease. Participation in physical and leisure activities throughout an individual's lifetime is receiving increased attention regarding the beneficial effects on cognition in advanced age (Kramer & Erickson, 2007; Verghese et al., 2003; Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001). While previous investigations have focused on leisure and physical activities, they have not clearly accounted for whether these activities afford a cognitively stimulating effect that may account for prevention of age-related cognitive declines, in part because of the difficulty in quantifying cognitive activities (Sturman et al., 2005). In general, physical activity has been considered beneficial for cognition, although the specific moderating factors have been unclear related to the relative contribution of aerobic exercise, social interaction, or cognitive stimulation (Kramer & Erickson, 2007; Larson, 2006). Despite the influence of physical activity on brain function, it is conceivable that there may be multiple lifestyle factors that are necessary for prevention of age-related cognitive decline (Sturman et al., 2005), and it has been suggested that frequent participation in cognitively stimulating activities may reduce the risk of Alzheimer's dementia (Wilson et al., 2002). In an attempt to identify modifiable lifestyle factors that may potentially enhance successful aging, we evaluated how musical instrumental participation throughout the life span may influence cognitive aging. To evaluate how years of musical activity predicts cognition in advanced age, we evaluated neuropsychological performance in low versus high activity musicians.

There is evidence supporting an association between lifelong cognitive stimulation and increased cognitive reserve that may reduce the likelihood of functional cognitive impairments in advanced age (Wilson, Barnes, & Bennett, 2003; Wilson et al., 2002). However, few studies have evaluated if there are experience-based attenuations of age-related cognitive declines by capitalizing on study of individuals who are highly practiced and skilled in a specific domain like music (Meinz & Salthouse, 1998). Musical participation is easily quantified in terms of number of years of training or participation, and there is data supporting differential brain organization for amateur musicians (Gaser & Schlaug, 2003; Koelsch, Jentschke, Sammler, & Mietchen, 2007; Tervaniemi, Castaneda, Knoll, & Uther, 2006). Therefore, the investigation of amateur musicians and nonmusicians offers an excellent model for how deliberate long-term practice and engagement in cognitively stimulating activities may alter brain development and influence cognition (Bangert et al., 2006).

Musical leisure activities, including playing an instrument, listening to music, and creating music, stimulate a variety of cognitive functions and may be informative regarding training induced brain plasticity that may be recruited in advanced age to compensate for age-related cognitive declines (Monaghan, Metcalfe, & Ruxton, 1998; Zatorre & McGill, 2005). Successfully acquiring musical expertise requires at least a decade of training, which typically begins at an early age and includes intensive repetitive practice that may result in plastic brain reorganization. Evidence suggests that musical activity may be associated with cortical reorganization including enhanced sensorimotor functions in young instrumental musicians (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005; Lotze, Scheler, Tan, Braun, & Birbaumer, 2003; Meister et al., 2005; Pantev et al., 1998; Peretz & Zatorre, 2005; Schmithorst & Wilke, 2002; Zatorre, Belin, & Penhune, 2002; Zatorre, Chen, & Penhune, 2007). There is also a growing body of literature suggesting that musical training may shape motor and cognitive functions in early development (Costa-Giomi, Gilmour, Siddell, & Lefebvre, 2001; Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Ho, Cheung, & Chan, 2003; Koelsch et al., 2005; Penhune, Watanabe, & Savion-Lemieux, 2005; Schellenberg, 2004). However, most of these developmental studies are correlational, with few experimental studies that have effectively randomized subjects into musical and nonmusical groups, and thus causation between musical participation and enhanced cognition remains uncertain (Schellenberg, 2004). The shortcomings of previous studies coupled with inconsistent findings have fueled significant controversy surrounding the relationship between musical activity and cognition. Furthermore, there are virtually no studies examining how extent of musical experience throughout the life span may influence maintenance of cognitive functioning in advanced age (Grant & Brody, 2004; Halpern, Bartlett, & Dowling, 1995; Halpern, Kwak, Bartlett, & Dowling, 1996; Meinz & Salthouse, 1998; Rauscher et al., 1997), although it has been hypothesized that professional musicians may be less likely to display dementia than nonmusicians, this has not been empirically tested (Grant & Brody, 2004).

Because musical training and experience utilize a wide variety of multisensory experiences, including motor functions, reading of musical notation, and auditory functions, it is possible that this could lead to transfer effects in a number of brain regions and cognitive areas (Schlaug, Norton, Overy, & Winner, 2005). Structural differences identified in brain regions closely linked to skills acquired during instrumental musical training are not surprising, although it remains unclear if there are structural brain differences outside these primary regions that suggest transfer to nonmusical cognitive abilities (Schlaug et al., 2005). Overall, the previous studies have indicated that there are differences in cortical organization associated with extended repetitive practice in musicians as well as differences in white matter architecture (Schmithorst & Wilke, 2002). However, controversy remains regarding the hemispheric specialization of musical abilities and how this lateralization might influence nonmusical cognitive abilities (Schellenberg, 2001).

There are relatively few studies evaluating the nonmusical cognitive functions of instrumental musicians, and most of these studies are correlational studies of young adults that have revealed inconsistent findings. Previous studies of cognition in young musicians have demonstrated enhancement of verbal memory abilities (Chan, Ho, & Cheung, 1998; Ho et al., 2003), auditory learning (Fujioka et al., 2006), and language functions (Barwick, Valentine, West, & Wilding, 1989; Patel & Iversen, 2007; Tallal & Gaab, 2006) consistent with auditory processing advantages in musicians for the left hemisphere (Patel, 2003). Advantages in visuospatial abilities (Costa-Giomi, 1999; Costa-Giomi et al., 2001; Hassler, Birbaumer, & Feil, 1985; Rauscher et al., 1997; Rauscher & Zupan, 2000) have been reported in agreement with right hemisphere dominance for the processing of musical properties and notation (Forgeard, Winner, Norton, & Schlaug, 2008). However, in general, the evidence for transfer effects from musical training to spatial skills and language skills have been mixed and require further investigation.

This study was designed as a preliminary study to evaluate whether there are differences in cognitive functioning in advanced age based on years of instrumental musical participation. We evaluated whether older individuals who participated in at least 10 years of musical experience displayed better cognitive performance than age and education matched individuals with less musical experience. To evaluate how years of participation influence cognitive functioning, we selected subjects based on the extent of instrumental musical engagement across the life span; no experience, fewer than 10 years activity, and more than 10 years of activity.

Methods

The experiment evaluated the neuropsychological profiles of older adults based on the extent of previous experience as instrumental musicians relative to nonmusicians. Subjects were classified according to their participation throughout their life span as amateur musicians and not their current participation in musical activities. However, subjects in the high activity group were more likely to continue playing in advanced age, with half of the high activity musician group actively engaged in music at the time of the experiment. Subjects were recruited from the Landon Center on Aging normal control database at the University of Kansas Medical Center (KUMC). All subjects underwent written informed consent in accordance with the KUMC Human Subjects Committee and according to the Declaration of Helsinki.

Participants

Seventy older healthy adults between 60 and 83 years of age with three different levels of musical activity across the life span participated in the neuropsychological experiment. The three groups were matched on age (M = 70 years; see Table 1) and education (M = 17), and the composition of each group was similar in terms of participation of males (40–50%) and females (50–60%). All subjects were native English speakers, strongly right hand dominant as determined by the Edinburgh Handedness Inventory (Oldfield, 1971), and had normal cognition (i.e., within-normal limits on the Mini-Mental Status Examination, MMSE; Folstein, Folstein, & McHugh, 1975). All subjects were healthy older individuals who were fully independent in activities of daily living and who did not display symptoms or signs of psychiatric or neurologic disease, current alcohol or substance abuse, or depression. The three groups did not differ significantly in their responses to an exercise questionnaire that quantified the frequency and duration of aerobic or anaerobic exercise activities, $F(2, 66) = .73$, *ns*.

Participants were subdivided into the following three groups based on their level of musical activity across the life span: 1) *nonmusicians* (n = 21) consisted of subjects who had never received formal training as an instrumental musician and could not play an instrument or read music; 2) *low activity musicians* (n = 27) consisted of individuals who had experience playing a musical instrument for at least 1 year but less than 9 years and had some formal training; and 3) *high activity musicians* (n = 22) consisted of individuals who had at least 10 years of experience playing a musical instrument on a regular basis, and formal training. Only three subjects in the *low activity* group endorsed musical engagement at the time of the experiment, while close to half of the high activity sample continued to play at the time of the assessment (see Table 1).

The musician groups did not differ in the age of instrumental acquisition, $F(1, 47) = .138$, *ns*, the years of formal musical training, $F(1, 47) = .548$, *ns*, but were significantly different in the number of years actively playing their musical instrument, $F(1, 47) = 44.05$, $p < .0001$ (see Table 1 for summary data). A larger proportion of the high activity musicians endorsed playing multiple instruments (86.4%), while the majority of the low activity musicians indicated they only played one primary instrument (66.7%). The most common primary instruments were the piano (51.9% low activity group; 68.2% high activity group), followed by woodwinds (25.9% low activity group; 22.7% high activity group). String instruments, percussion, and horn instruments were also reported by some subjects but with very low frequency. During the years of active musical participation, subjects estimated the frequency of playing on a daily (33.3% low activity; 40.9% high activity), weekly to bimonthly (22.2% low activity; 31.8% high activity), or semiannual or annual basis (44.5% low activity; 27.3% high activity). In both groups, the most common style of music was classical (51.9% low activity; 45.5% high activity), followed by popular music (33.3% low activity; 22.7% high activity).

Neuropsychological Assessment

A comprehensive neuropsychological assessment was administered to determine differences in the profile and cognitive strengths between musicians and nonmusicians. The assessment was administered in one session and included several estimates of verbal intellectual functioning, memory, attention, working memory, and language functions. An estimate of premorbid verbal intelligence was based on the American Adult Reading Test (AMNART), which requires subjects to read out loud irregular words that cannot be correctly pronounced utilizing rules of phonics. The AMNART provides a good estimate of Wechsler Adult Intelligence Scale (WAIS) Verbal IQ and is a stable and valid measure of premorbid intellectual functioning in older non-demented and demented adults (Grober & Sliwinski, 1991). The Information subtest of the WAIS-III was also administered, and provides a good estimate of general intellectual ability and verbal intelligence, which is stable with advanced age (Wechsler, 1997a). Verbal memory performance was measured by the California Verbal Learning Test, Second edition (CVLT-II, short version; Delis, Kramer, Kaplan, & Ober, 2000), while nonverbal memory was measured by the Wechsler Memory Scale Third Edition (WMS-III) Visual Reproduction I and II subtests (Wechsler, 1997b). Auditory attention was measured by the Digit Span (DS) subtest of the WAIS-III, while auditory working memory was measured by the Letter-Number Sequencing (LNS) subtest of the WAIS-III (Wechsler, 1997a). Visual attentional functions included the Spatial Span (SS) subtests of the WMS-III (Wechsler, 1997b), Trails A, and Trails B, which also measure cognitive flexibility by asking the subject to switch rapidly between numbers and letters (Reitan & Wolfson, 1993). Verbal and language functions were measured with the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983) and semantic (animals) and phonemic (FAS) fluency (Benton, Hamsher, & Sivan, 1994).

Results

Several analyses of variance (ANOVA) were conducted on the neuropsychological measures to determine between-groups differences based on level of musical participation across the life span (nonmusicians, low activity musicians, high activity musicians). Significant univariate analyses were followed by post hoc comparisons with Bonferroni correction.

Estimates of Verbal Intellectual Ability

ANOVAs evaluating verbal intellectual ability did not reveal between-groups differences for either the AMNART, $F(2, 67) = 2.56$, *ns*, or the Information subset of the WAIS-III, $F(2, 67) = 1.77$, *ns* (see Table 2 for means). Although the estimated verbal intellectual abilities of norunusicians were slightly lower than musicians, this was not statistically significant.

Memory

Verbal learning and memory recall measures were not significantly different between-groups (CVLT-II Total, CVLT-II Short Delay Free Recall, CVLT-II Delayed Recall; CVLT-11 Recognition; see Table 2). Although the groups did not differ on the immediate nonverbal recall of the Visual Reproduction test (VR I), $F(2, 67) = 10.34$, *ns*, there was a significant between-groups difference on the delayed nonverbal memory recall of the Visual Reproduction (VR II),$F(2, 67) = 29.39$, $p = .02$ (see Figure 1). Post hoc analyses with Bonfenoni revealed that the high activity musicians had greater nonverbal recall compared to norunusicians (Mean difference = −2.31, $SE = .830$, $p = .007$; see Figure 1). There were no significant differences in nonverbal memory recall between the norunusicians and low activity musicians (Mean difference = .873) or between low activity and high activity musicians (Mean difference = −1.43; see Table 2).

Attention and Working Memory

ANOVAs for Digit Span and Letter Number Sequencing did not reveal significant between-groups differences for auditory attention and working memory functions (see Table 2). However, between-subjects effects were significant for visuomotor speed (Trails A), $F(2, 67) = 3.212$, $p < .05$, and visuospatial sequencing and cognitive flexibility (frails B), $F(2, 67)$ 5.071, $p < .01$, but not for a simple measure of visual attention (WMS-ID Spatial Span), $F(2, 67) = 2.854$, $p = .07$, which approached significance. Post hoc analyses with Bonfenoni revealed that high activity musicians were faster in processing speed and visual search on Trails A than low activity musicians (Mean Difference = −1.55; $SE = .623$; $p = .045$), and that high activity musicians were faster than norunusicians on Trails B which adds additional executive and visuospatial demands (Mean Difference = −2.063; $SE = .668$; $p = .009$; see Table 2 and Figure 1).

Language

Semantic and letter fluency perfonnances did not reveal significant between-groups differences (see Table 2), although letter fluency approached significance ($p < .08$). However, the Boston Naming Test was different between the music groups, $F(2, 67) =$

3.861, $p < .03$, with high activity musicians displaying significantly better word retlieval than nonmusicians (Mean Difference = −2.171; *SE* = .781; $p = .021$; see Figure 1).

Musical Participation in Advanced Age

Since many of the high activity musicians remained musically engaged in advanced age, we evaluated whether cognitive performance varied as a function of current musical participation. The results were insignificant across all cognitive measures, with the exception of the immediate recall for nonverbal designs (VR I of the WMS-III), $F(1, 20) = 4.41$, $p < .05$ (Mean difference = −1.9). Continued musical activity in advanced age did not account for any of the significant findings between high activity musicians and nonmusicians including delayed nonverbal memory recall (VR II WMS-III), $F(1, 20) = 1.32$, *ns*; visuomotor speed (Trails A), $F(1, 20) = .018$, $p = ns$; visuospatial sequencing and cognitive flexibility (Trails B), $F(1, 20) = .107$, *ns*; or naming (BNT), $F(1, 20) = 1.6$, *ns*. Also, high activity musicians currently engaged in musical activities ($n = 11$) did not differ in estimates of verbal intelligence on the AMNART, $F(1, 20) = 2.3$, $p < ns$, or the Information subset of the WAIS-III, $F(1, 20) = .088$, *ns*, compared to inactive musicians ($n = 11$).

Discriminant Analysis

A discriminant analysis was used to identify classes of neuropsychological predictors that achieved accurate music group classification. The neuropsychological measures found to reveal significant differences between music groups were entered as predictors. The following tests (function 1) achieved 57.1% correct classification for all groups ($p = .029$; Table 3): visuospatial sequencing and cognitive flexibility (Trails B), nonverbal memory delayed recall (VR II WMS-III), and naming accuracy (BNT). Visuomotor speed on Trails A (function 2) did not produce a significant increment in group classification accuracy. The neuropsychological tests were most successful in classifying the high activity musicians (77.3%), although 5 of the 22 subjects were misclassified as in either the low activity or nonmusical group (three as nonmusicians). Eight of the nonmusicians were classified as musicians, while the low activity musicians were equally classified in all three groups, demonstrating the variability of cognitive functioning for the low activity musicians (see Table 3).

Regression Analyses for Musician Groups

Several stepwise regressions were performed on the neuropsychological tests with significant between-groups differences to evaluate predictors of cognitive performance for the musicians ($n = 49$) for the following tests: Trails A, Trails B, BNT, VR I, and VR II of the WMS-III. Stepwise regression analyses were conducted with the following predictors entered into the equation: age, education, estimated verbal intelligence (AMNART), years of musical activity, instrument type, type of musical training (private, group, school, etc... .), frequency of playing, current musical activity, and frequency of physical exercise (Table 4). The first regression revealed that age of musical acquisition was the best predictor of immediate recall of visual designs, VR I WMS-III: $F(1, 47) = 8.39$, $p < .01$, explaining 13.4% of the variance. Conversely, years of musical activity was the best predictor of delayed nonverbal memory recall, VR II: $F(1, 47) = 7.08$, $p < .01$, followed by age of musical acquisition, $F(2, 46) = 6.124$, $p < .005$, accounting for 11.2% and 6.4% of the variance, respectively. On the BNT, age, $F(1, 47) = 8.17$, $p < .01$, type of musical training, $F(2, 46) = 9.74$, $p < .0001$, and physical exercise, $F(3, 45) = 8.8$, $p < .0001$, significantly explained 13%, 13.7%, and 6.3% of the variance (total variance of 33%), respectively. Age was the best predictor of Trails A speed, $F(1, 47) = 6.52$, $p < .01$, explaining 10.3% of the variance. The addition of years of musical activity, $F(2, 46) = 6.28$, $p < .005$, and physical exercise, $F(3, 45) = 5.9$, $p < .005$. increased the variance by 8% and 5.5%, respectively (total variance explained 23.5%). On Trails B, age explained 18.5% of the variance in processing speed, $F(1, 47) = 11.93$, $p < .001$, while the addition of current musical activity increased the variance by an additional 5.2%, $F(2, 46) = 8.44$, $p < .001$.

Discussion

The current study examined the cognitive differences of older healthy subjects based on extent of instrumental musical experience across the life span. We matched the groups on education, intelligence, physical exercise participation, and the musicians on age of musical acquisition and years of formal instrumental training. The results of the study revealed significant differences between high activity musicians and nonmusicians on measures of naming, nonverbal memory recall, visuomotor speed, visuomotor sequencing, and cognitive flexibility. Although cognitive differences between low and high activity musicians were not statistically significant, the cognitive performance of low activity musicians fell in-between that of nonmusicians and high activity musicians, demonstrating a linear relationship between years of musical participation and cognitive functioning in advanced age. The age of acquisition was similar for both low and high activity musicians, suggesting there were no significant differences related to learning at different critical sensitive periods. Therefore, the primary difference between the groups was the actual years of instrumental practice across the life span, although high activity musicians were also more likely to be playing at the time of the evaluation (50% of the sample) when compared to low activity musicians (11% of the sample). Since the active status of the high activity musicians could not account for the cognitive differences between the groups, this suggests that years of musical participation throughout the life span influences cognitive functioning in advanced age. However, given the correlational nature of our study, we are not able to exclude the possibility that there may have been specific selection factors that may have determined which subjects engaged in musical activities for a longer period of time. Conceivably, individuals with higher intelligence may be more likely to persist with musical activities for a longer period of time.

Nonetheless, the finding that cognitive functioning in advanced age is linearly related to the number of years of musical participation argues for the possibility of a robust and sustained effect of musical training on cognition. This finding was further supported by the results of the regression analysis that revealed that the years of musical training was the best predictor of nonverbal memory recall, even after controlling for age, education, estimated verbal intelligence, and physical activity. Similarly, years of formal musical training significantly accounted for variance in Trails A, although physical exercise also proved to be important demonstrating that both cognitive and physical aspects of activities may be important modifying factors in advanced age. Similarly, BNT performance was predicted by the type of musical training as well as physical exercise. The type of training may either be an indication of the intensity of musical activity or, alternatively, reflective of which individuals were likely to pursue or have access to private training sessions. Despite the lack of group differences between active and inactive musicians, current musical activity was a significant predictor of Trails B performance, which requires a combination of visuomotor speed, visuospatial sequencing, and cognitive flexibility. Finally, age of acquisition predicted performance variance for both the immediate and delayed recall of Visual Reproduction of the WMS-III, suggesting that the timing of cognitive stimulation during critical sensitive periods may be a critical factor. Although our preliminary results suggest that both musical and physical activity are important contributors to cognitive vitality in advanced age, our results are not capable of teasing apart potential social influences. Thus, the multidimensional aspects of musical participation will require further investigation to better understand the relative social, physical, and cognitive components of musical activity that may influence cognitive and brain aging.

Our results are consistent with previous investigations demonstrating enhanced cognition in children engaged in musical activity and long lasting cognitive changes with formal exposure to music (Forgeard et al., 2008; Schellenberg, 2004, 2006). However, our results differ in the type of memory advantage previously reported in young adults (Chan et al., 1998; Ho et al., 2003). Contrary to other studies, our findings revealed better visual design retention and enhanced visuospatial sequencing in high activity musicians, consistent with investigations reporting visuospatial advantages in musicians (Costa-Giomi et al., 2001; Gardiner, Fox, Knowles, & Jeffrey, 1996; Rauscher, Shaw, & Ky, 1993; Rauscher et al., 1997). Conversely, a recent study evaluating the influence of instrumental musical training in children did not reveal visuospatial improvements but enhancements in nonverbal reasoning and verbal ability (Forgeard et al., 2008). The nonverbal reasoning finding is consistent with our finding of enhanced cognitive flexibility and nonverbal memory, while the verbal ability finding corresponds to the trend for advanced musicians to have higher verbal IQ as was also reported in a previous study (Ho et al., 2003). Therefore, it is conceivable that taking music lessons may enhance general IQ (Schellenberg, 2004) or alternatively that individuals with greater intelligence are more likely to engage in musical activities. Moreover, since most estimates of intelligence rely heavily on verbal measures, it is difficult to discern which of these two alternatives explain the findings. In general, given the parallels between music and language, it is plausible that musical participation may enhance verbal abilities (Patel & Iversen, 2007).

In previous investigations of young musicians, there has been considerable controversy regarding the association between music and cognition and whether musical experience enhances cognitive functions in a specific or general fashion (Schellenberg, 2006). Based on findings of associations between musical abilities and specific cognitive abilities (i.e., spatial abilities, verbal or language abilities), some investigators have concluded that musical abilities have specific cognitive correlates that are enhanced (Chan et al., 1998; Rauscher et al., 1997; Rauscher & Zupan, 2000). Conversely, proponents of the generalist view of musical abilities argue that musical experience has a general influence on intelligence, which is not specific to any one cognitive domain (Schellenberg, 2004, 2006). Our results support the postulate that the influence of musical training on cognition is more general than previously discussed specific links with language (Schellenberg & Peretz, 2008) and suggest that musical experience may also influence visuospatial and executive cognitive domains.

Consistent with the controversial hypothesis that musical expe-

rience may improve verbal abilities, the high activity musicians in our study displayed increased performance on the BNT in addition to higher estimates of Verbal IQ. Additionally, the high activity musicians displayed significantly better performance on the Trails B test, a measure of cognitive flexibility. While the effect sizes for between groups differences in nonverbal memory and naming were similar, Trails B had the largest effect size of all the cognitive tests administered. The discriminant analysis revealed that a combination of naming, nonverbal memory recall, and executive function measures (Trails B) were capable of accurately classifying the high activity musicians with 77.3% accuracy. Conversely, Trails A, which measures visual attention and motor speed, did not provide significant discriminability. Furthermore, our results of a larger effect size for Trails B suggests that enhanced executive functions in adult musicians may play a role in mediating the compensation that facilitates performance across several cognitive measures (Schellenberg & Peretz, 2008). The results of this investigation reveal that the years of engagement in musical instrumental practice is associated with better performance on tests of naming, visuospatial memory, visuomotor speed, visuospatial sequencing, and cognitive flexibility. Furthermore, it is also conceivable that sustained musical activity in advanced age may maintain cognitive flexibility.

Our findings are in close agreement with a recent longitudinal study in children demonstrating enhanced verbal ability and increased reasoning skills with 3 years of musical training (Forgeard et al., 2008). Despite our verbal advantages evident in IQ and naming, our results did not reveal verbal memory advantages but nonverbal memory advantages. Consequently, future studies are needed to explore whether these differences are related to age-related changes in plasticity, selection factors, or general differences in cognitive abilities of musicians that might yield variable cognitive profiles. Future research should be aimed at clarifying whether musical effects are domain-general (general effect on intelligence of executive functions which yield improved performance in other cognitive domains) or domain specific and focused on eliminating the following noncausal explanations: family environment, motivation that may have influenced continued participation, or increased likelihood of participating in other cognitively engaging activities or being more active in general. Although we controlled for general exercise participation and education level, it is difficult to account for all the other alternative cognitively enhancing activities subjects may participate throughout their life span. It is conceivable that individuals more likely to participate in musical activities may also be more likely to engage in other cognitively stimulating activities throughout the life span and in advanced age.

It is noteworthy that the cognitive domains in which advanced musicians outperformed nonmusicians (memory, naming, executive functions) are consistent with susceptible areas of cognitive decline in advanced age viewed as suggestive of the possible development of a neurodegenerative process such as Alzheimer's disease. Although verbal memory functions have received greater focus in studies of aging, there is evidence that patients with Alzheimer's dementia also have nonverbal memory deficits as well as visuospatial deficits (Anderson et al., 2007; Paxton et al., 2007; Reed et al., 2007). In addition to prominent episodic memory deficits that signal the onset of Alzheimer's dementia, other domains of cognition including executive dysfunction, language and visuospatial functions are important (Grober et al., 2008). Frontal-executive deficits, such as those measured by Trails B, have demonstrated sensitivity to the prevalence of dementia and older individuals demonstrating both naming difficulties and memory retrieval difficulties have a higher risk of developing an Alzheimer's dementia (De Jager, Blackwell, Budge, & Sahakian, 2005).

Therefore, the neuropsychological profile of our advanced musicians suggests they may have cognitive advantages that may potentially provide cognitive reserve in advanced age. However, future investigations are needed to explore the mediating factors and neural mechanisms. There is growing evidence that lifestyle factors, including stimulating cognitive and leisure activities, may impact "cognitive reserve" and postpone the onset of Alzheimer's disease and other dementias. For example, there is evidence that multilingualism may maintain cognitive functioning (Kave, Eyal, Shorek, & Cohen-Mansfield, 2008) and that lifelong bilingualism may delay the onset of dementia symptoms in advanced age by as much as 4 years (Bialystok, Craik, & Freedman, 2007). Theories of the effect of multilingualism on cognition suggest that switching between several languages is likely to enhance cognitive flexibility, allowing reserve for better compensation in advanced age. It is conceivable that well documented cortical and white matter plasticity in musicians may provide additional cognitive flexibility, and this was supported by our finding that Trails B was the best predictor of musical participation. The reasons why musicians outperform nonmusicians are unclear from our findings, although it may be considered that musical training serves as additional education. Educational attainment has been reported to retard cognitive decline in advanced age and has demonstrated differences in recruitment of networks during memory tasks providing greater compensation (Springer, McIntosh, Winocur, & Grady, 2005).

However, the correlational design of our study does not allow us to comment on whether musical participation causally enhanced cognition or whether other variables were responsible for the findings. Future studies should focus on replication of cognitive domains enhanced in musicians, comparison to other cognitively stimulating activities, longitudinal studies, and studies evaluating neural mechanisms of compensation to help elucidate whether musical training may enhance cognition in advanced age. Given our findings that physical exercise significantly predicted naming performance and the extensive literature implicating physical exercise in cognition, the specific mechanisms of engaged activities requires more in-depth analysis. Furthermore, our study did not evaluate level of social engagement during musical participation as an alternative hypothesis for maintenance of cognition in musicians. Since engagement in social activities has been associated with cognitive vitality in advanced age, this warrants further investigation. While environmental influences on cognition and brain plasticity during aging have been identified, the relative social, physical and cognitive aspects of stimulation needed for desired cognitive outcomes remains uncertain.

Acknowledgments

This work was presented in part at the Mid-Year meeting of the International Neuropsychological Society, Bilbao, Spain, July 4–7, 2007. We thank Erin Douglass for assistance with initial data collection.

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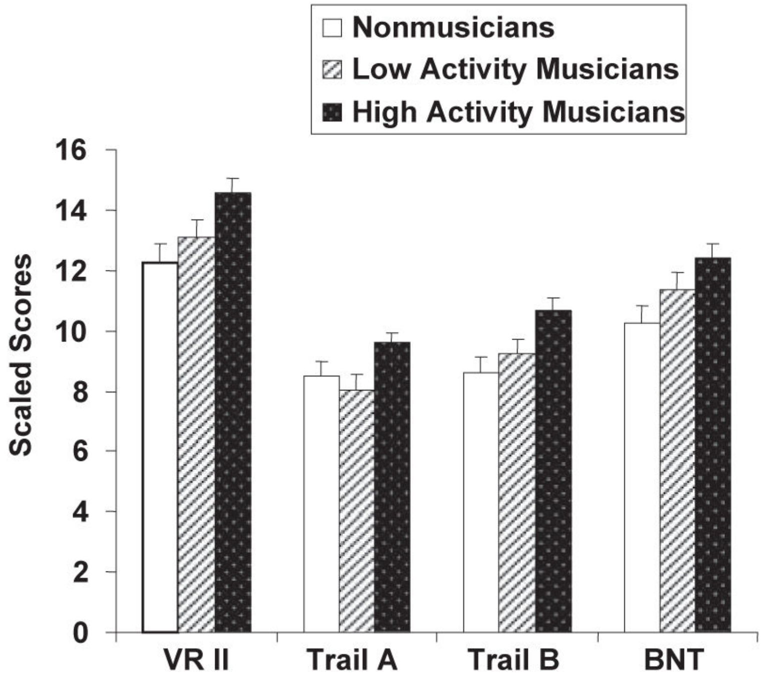

Figure 1.

Scaled scores for significant between-group results. VR II = Visual Reproduction Delayed Recall; BNT = Boston Naming Test.

Table 1

Means (SDs) of Subject Characteristics and Screening Measures

Total (*n* = 70)	**Nonmusicians (*n* = 21)**	**Low activity musicians (*n* = 27)**	**High activity musicians (*n* = 22)**
Age	69.7 (7.9)	69.5 (6.6)	70.8 (6.3)
Education	16.2 (2.5)	17.4 (2.2)	17.6 (2.6)
MMSE	29 (1.1)	29.3 (.87)	29.3 (.70)
Edinburgh Handedness Inventory	73 (52.5)	73.9 (36.4)	81.8 (16.6)
Years of formal musical training	0	3.3 (.95)	3.5 (.96)
Age of acquisition	0	10.4 (5.9)	9.7 (7.2)
Years actively playing instrument	0	3.8 (2.7)	35.5 (24.7)
Subjects playing multiple instruments	0	33.3%	86.4%
Currently playing	0	11.1%	45.5%

Note. MMSE = Mini Mental State Examination.

Table 2

Means (SD) and Summary Statistics for Neuropsychological Measures

Means (*SD*)	**Nonmusicians (*n* = 21)**	**Low activity musicians (*n* = 27)**	**High activity musicians (*n* = 22)**	***F***	**Sig.**	**Effect size**
AMNART- IQ	120.8 (6.8)	123.6 (4.8)	124.3 (4.5)	2.56	.082	.072
Information (SS)	12.6 (2.4)	13.7 (2.1)	13.5 (2.1)	1.77	.177	.05
CVLT-II Total	57.38 (10.03)	56.89 (9.19)	55.23 (12.33)	0.25	0.77	0.008
CVLT-II SDFR	0.50 (1.01)	0.54 (1.45)	0.86 (2.15)	0.35	0.71	0.010
CVLT-II LDFR	0.43 (1.26)	0.46 (0.84)	0.91 (2.00)	1.61	0.45	0.023
WMS-III VRI	9.67 (2.22)	10.74 (2.61)	10.95 (2.30)	10.34	0.18	0.051
WMS-III VRII	12.24 (3.02)	13.11 (2.83)	14.55 (2.24)	**29.39**	**0.02**	**0.106***
Digit Span	10.90 (2.59)	11.56 (2.28)	11.50 (3.19)	0.40	0.67	0.012
LNS	11.29 (2.39)	12.26 (1.81)	12.59 (2.99)	1.72	0.19	0.049
Spatial Span	9.95 (2.84)	11.85 (3.02)	11.64 (2.84)	2.854	0.07	0.078
Trails A	8.48 (2.18)	8.04 (2.55)	9.59 (1.56)	**3.212**	**0.05**	**0.087***
Trails B	8.62 (2.27)	9.26 (2.33)	10.68 (1.91)	**5.071**	**0.01**	**0.131***
Letter fluency	9.52 (3.14)	11.44 (2.55)	10.46 (2.97)	2.668	0.08	0.074
Semantic fluency	11.10 (2.61)	11.15 (2.63)	11.14 (1.86)	0.003	0.99	0.000
BNT	10.24 (2.57)	11.37 (2.80)	12.41 (2.22)	**3.861**	**0.03**	**0.103***

Note. AMNART-IQ = American Adult Reading Test; CVLT-II = California Verbal Learning Test Second Edition; SDFR = Short Delay Free Recall; LDFR = Long Delay Free Recall; WMS-III = Wechsler Memory Scale Third Edition; VR I = Visual Reproduction Immediate Recall; VR II = Visual Reproduction Delayed Recall; LNS = Letter Number Sequencing; BNT = Boston Naming Test.

Table 3

Results of Discriminant Analysis and % Correct Classification

	Predicted Group Membership		
	Nonmusicians	**Low activity**	**High activity**
Nonmusicians	**61.9%**	19%	19%
Low activity	37%	**37%**	25.9%
High activity	13.6%	9.1%	**77.3%**

Table 4

Predictors of Cognitive Performance for Musicians Based on Stepwise Multiple Regressions

	B	***SE*(B)**	β	***t***	***Sig. p***
Visual Reproduction I					
WMS-III					
Age of acquisition	.147	.051	.389	2.89	.006
Visual Reproduction II					
WMS-III					
Years playing	.047	.015	.403	3.05	.004
Age of acquisition	.117	.054	.285	2.15	.037
Trails A					
Current age	−.163	.047	−.458	−3.49	.001
Years playing	.032	.013	.322	2.48	.017
Physical exercise	−.081	.039	−.264	−2.07	.044
Trails B					
Current age	−.137	.046	−.388	−2.991	.004
Current musical activity	.208	.102	.264	2.038	.047
Boston Naming Test					
Current age	−.209	.05	−.517	−4.20	.000
Training	.941	.338	.347	2.78	.008
Physical Exercise	−.098	.042	−.280	−2.03	.026