The effects of musical training on verbal memory

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ABSTRACT A number of studies suggest a link between musical training and general cognitive abilities. Despite some positive results, there is disagreement about which abilities are improved. One line of research leads to the hypothesis that verbal abilities in general, and verbal memory in particular, are related to musical training. In the present article, we review this line of research and present newly collected data comparing trained musicians to non-musicians on a number of tasks that recruit verbal memory. The results showed an advantage for musicians' long-term verbal memory that disappeared when articulatory suppression was introduced. In addition, we found evidence for a greater verbal working memory span in musicians. Together, these results show that musical training may influence verbal working memory and long-term memory, and they suggest that these improved abilities are due to enhanced verbal rehearsal mechanisms in musicians.

KEYWORDS: *articulatory suppression, memory span, working memory*

Introduction

The question of whether the benefits of music training extend beyond musical abilities per se has been asked by a number of researchers. While there is often variability in findings relating to this question, training studies and studies comparing skilled musicians to non-musicians have revealed two domains of non-musical skill that tend to benefit from musical training: spatial abilities (Bilhartz et al., 1999; Costa-Giomi, 1999; Drake and Palmer, 2000; Gaser and Schlaug, 2003; Hassler et al., 1985; Leng et al., 1990; Rauscher and Zupan, 2000; Rauscher et al., 1995) and verbal memory (Brandler and Rammsayer, 2003; Chan et al., 1998; Helmbold et al., 2005; Ho et al., 2003; Ohnishi et al., 2001; Schlaug et al., 1995a). In this article, we focus on the reported verbal memory advantage for musicians.

One of the first studies to show a verbal memory advantage for musicians was conducted by Chan et al., (1998). They compared skilled musicians who had at least six years of training to controls with no musical training. Participants were administered a verbal learning task in which they heard a list of 16 words read aloud three times and had to recall as many words as possible each time the list was read. The results showed that the musicians had significantly higher recall scores than the non-musicians. In another study by Jakobsen et al. (2003), adults with a wide range of musical training performed a list-learning task, having to report on the order of syllables that were presented aurally. This task was designed to investigate verbal working memory. The authors found a positive correlation between years of musical training and performance on this task. They suggested that musical training might have enhanced auditory temporal processing skills, allowing for fine discriminations among rapidly changing acoustic events. A third study by Brandler and Rammsayer (2003) provides an even stronger account of the specific relationship between musicality and verbal skills, as verbal memory was the only cognitive test from an entire battery that showed a difference between musicians and non-musicians.

It should be noted, though, that not all studies investigating verbal memory for musicians have yielded similar results. In a follow-up study to that by Brandler and Rammsayer (2003), perceptual speed of processing was the only test that showed a difference between musicians and non-musicians (Helmbold et al., 2005). Because this study had twice as many participants as the original, and because it better controlled for variables such as sex, age, and level of education, the authors concluded that their previous results revealing a verbal memory advantage for musicians may have been due to sampling error. However, studies that utilize training protocols, as described below, have also revealed these verbal memory effects, suggesting that the previously discussed findings cannot be so easily dismissed.

The studies discussed so far involve groups of participants who either already have musical training, or do not. Because of this, it becomes difficult to determine whether group differences (i.e. between musicians vs. non-musicians) are because of musical training or instead are related to other factors such as personality or motivation that lead people to pursue extensive training in music. In contrast, training studies involve randomly assigning children to different groups, administering musical training to the experimental group, and then comparing the experimental group to untrained controls on cognitive tasks. These studies offer stronger evidence for the relationship between verbal memory and training in music because they involve random assignment and experimental manipulation, and therefore they eliminate self-selection factors.

In one such study, Ho et al., (2003) showed that musical training improves verbal but not visual memory skills. They used a hybrid cross-sectional and longitudinal design involving 90 children aged six to 15 years, each having one to five years of musical training. In the cross-sectional part of the study, the researchers tested children at different stages in their chronological and musical development on both verbal and visual memory tasks. Musical training correlated significantly with verbal but not visual memory. The longitudinal aspect of the study included a one-year follow-up of these children as well as new ones who had just started music lessons. Three groups were formed: those with experience who continued lessons; those with musical training who discontinued their lessons; and those who were new to musical training. At pre-test, the beginners performed worse than the musically experienced groups on a verbal memory task, but at post-test, they had caught up with the children who had discontinued lessons. The experienced children who continued lessons performed the best. In the visual memory tasks, all children improved equally, though there was a trend toward lessons making a positive difference. The training portion of this study thus shows that verbal but not visual-spatial memory may be improved with musical training.

In a comprehensive study involving 144 six year olds, Schellenberg (2004) demonstrated that children exposed to one school-year of musical training had a greater increase in IQ-score as compared to children who were in control conditions. IQ was primarily measured using the Wechsler Intelligence Scale for Children – Third Edition (WISC–III; Wechsler, 1991), which contains a variety of subscales that examine particular subsets of intellectual abilities, such as verbal and spatial-temporal skills. There were two music groups, one of which received keyboard and the other voice lessons. In order to demonstrate that musical training is special above and beyond arts lessons more generically, one of the control groups received drama lessons while the other received no lessons. While all groups significantly improved in IQ, likely because of starting their first year of formal schooling, the music-lesson groups improved their IQ scores by an additional three points compared to the drama and no-lessons groups. The increase in IQ was distributed across different subtests, including those that measure verbal memory. Since the advantages for trained musicians on these tests were not uniquely related to verbal memory, Schellenberg concluded that musical training causes general improvement in cognition.

In addition to the training studies and studies comparing musicians to non-musicians, there is also neuro-imaging evidence consistent with improved verbal memory for musicians. A study by Ohnishi et al. (2001) used functional magnetic resonance imaging (fMRI) to investigate differences in cortical activation between musicians and non-musicians during a passive listening task. The results provide evidence linking musical expertise to verbal areas. Specifically, the authors found differences between musicians and non-musicians in the degree of activation of the planum temporale (PT) and left dorso-lateral prefrontal cortex (DLPFC), with musician's showing greater activation. The left PT, also known as Wernicke's area, is associated with language comprehension. The authors found that the degree of activation in the PT was correlated with the age at which the participant started musical training. Schlaug and colleagues (1995a) reported results consistent with this study when comparing structural MRI images of musicians and non-musicians. Specifically, they discovered that there was more PT asymmetry (larger on the left side) in musicians than in non-musicians. The authors described this asymmetry as potentially relating to language and pitch-processing skills. In addition to these MRI studies, a number of studies using EEG have shown that when musicians and non-musicians are compared, musicians often demonstrate greater left-hemisphere lateralization when presented with musical stimuli (Besson et al., 1994; Bever and Chiarello, 1974; Hishkowitz et al., 1978). Additionally, a recent study by Fujioka et al. (2006) used magnetoencephalography (MEG) to compare brain activation of four to six year olds while listening to violin tones. Several MEG components were shown to become more left-lateralized in a subset of the participants who received music lessons throughout a year. Together, these studies support the idea that musical training may affect brain structures relating to verbal abilities and verbal memory in particular.

In the present study, we sought to investigate further the link between musical training and verbal memory with trained musicians and non-musicians equated in age, education, standardized testing scores (SATs), grade-point average (GPA), and scores on the Raven's Advanced Progressive Matrices Test (often used to test for fluid intelligence). In phase 1, we tested the long-term verbal memory effect, attempting to replicate the verbal memory advantage reported by Chan et al., (1998) by using a standardized memory test (the RAVLT).[1] In phase 2, we extended this work by introducing articulatory suppression within the same verbal memory test in order to interfere with verbal rehearsal processes. We also tested working memory for verbal information using the reading-span and operation-span tasks. Based on previous work, we hypothesize that musicians would have an advantage for verbal memory and that because this advantage may be because of an enhanced verbal rehearsal mechanism, articulatory suppression should eliminate musicians' advantage on this task. Also, we expected musicians to perform better on verbal *working* memory tasks as well as verbal long-term memory tasks because of their taking advantage of a more developed verbal rehearsal mechanism.

Methods

Data were collected from two groups of participants, musicians and non-musicians. The trained musicians all conformed to the following criteria:

- formal training in music began at age 10 or younger;
- at least nine years of continuous training in music;
- currently played and practiced at least 15 hours/week;
- enrolled in an undergraduate or graduate music program; and
- a self-rated sight-reading skill of 4 or better on a seven-point scale.

The controls were recruited for the study based on the following criteria:

- did not currently play an instrument;
- no history of playing an instrument prior to age 10;
- never played an instrument for longer than one year; and
- a self-rated sight-reading skill of 1 on a seven-point scale.

We also collected demographic information from all participants which included education level, GPA, and standardized testing scores (SATs or ACTs, which we converted to the same scale as the SAT scores for uniformity).

The experiment was conducted in two phases. For phase 1, we tested 12 musicians and 13 non-musicians. In phase 2, there were 11 musicians and 9 non-musicians. Tables 1 and 2 display participants' demographic information for phases 1 and 2 including gender, age, education, SAT and GPA. Also included are the p-values calculated from the t-tests (two-tailed) comparing musicians to non-musicians on these variables. Education was calculated by assigning participants a number according to the amount of education (freshman = 1, sophomore = 2, junior = 3, senior = 4, BA/BS = 5, master's = 6)[2]. There were no statistically significant differences between musicians' and non-musicians' education, GPA, or SAT levels (all p-values $>.05$).

TABLE 1 *Demographic information and the* p-*values for a two-tailed* t-*test comparing musicians and non-musicians in phase 1*

	Musicians ($N = 12$)	Non-musicians ($N = 13$)	p-value
Gender	9 females	10 females	
SAT	1283.54	1250.83	0.67
Education	2.07	2.84	0.08
Age	19.53	19.92	0.36
GPA	3.32	3.42	0.71

TABLE 2 *Demographic information and the* p-*values for a two-tailed* t-*test comparing musicians and non-musicians in phase 1*

	Musicians ($N = 11$)	Non-Musicians ($N = 9$)	p-value
Gender	4 females	6 females	
SAT	1256.67	1295.71	0.64
Education	3.81	3.40	0.57
Age	21.90	21.30	0.69
GPA	3.33	3.02	0.36

RAVEN'S ADVANCED PROGRESSIVE MATRICES TEST

The Raven's test was administered to all participants as a measure of fluid intelligence. In this test, participants are shown a pattern consisting of eight figures with a ninth missing, and they are asked to select from among eight choices the figure that completes the pattern. There are 36 items in the test. This test measures what is often referred to as fluid intelligence – the ability to develop new insights and to form largely non-verbal constructs that facilitate the handling of complex problems. As participants move through the task, the problems become progressively more difficult.

REY AUDITORY VERBAL LEARNING TEST (RAVLT)

The RAVLT uses a list-learning paradigm to measure participants' verbal memory capacity. A list of 15 words (list A) is read aloud at the rate of one word per second. At the end of the list, participants are instructed to recall as many words as they can, in any order. This process is repeated four more times for a total of five 'learning' trials. Following the fifth learning trial, a different, interfering list (list B) is read, and participants are asked to recall the words from this list. Immediately following this recall, participants are again asked to recall the words from List A (without hearing the list again). After a 30-minute delay, participants are asked to recall the words from list A yet again. Finally, as a recognition test, participants are shown a list of 30 words, and are instructed to select the words from the list that they recognize as being part of list A. In Phase 1 of our experiment, participants were administered the RAVLT in its canonical form, as just described. In phase 2, participants were given the additional instruction of saying the word 'the' between each word read from the list, an implementation of the technique of articulatory suppression (Baddeley et al., 1975). Articulatory suppression is a technique that prevents participants from rehearsing verbal material to aid its storage in working memory and to aid in the transfer of this information into long-term memory. This technique has not been used in other studies that investigate musicians' verbal memory skills. We used articulatory suppression to probe whether any potential differences in verbal memory between musicians and non-musicians might be due to differences in strategies used to aid memorability, rather than to a structural difference in the memory stores themselves between the groups of participants. If musicians' performance changes (i.e. performance decreases) with articulatory suppression more than control participants, this would suggest that an overt rehearsal strategy is being used to benefit performance. Superior performance for musicians in the RAVLT with articulatory suppression would suggest that there is not an underlying rehearsal strategy that aids musicians' verbal memory; rather, increased performance is likely because of a general ability to store more verbal information.

VERBAL WORKING MEMORY

Two tests of verbal working were administered during phase 2. These were the reading span and operation span tasks.

Reading span

The reading span task is designed to assess verbal working memory. On each trial, participants are shown a sentence (which may or may not make sense) followed by a question mark and then a capitalized letter. They are asked to read the sentence aloud, say aloud whether the sentence makes sense or not ('Yes' or 'No'), and then finally read the capitalized letter out loud. After a certain number of trials, (from two to five, depending on the set) participants must recall and write down as many of the letters as they can from that particular set, in correct serial order.

Operation span

The operation span task is very similar to the reading span task, and is also designed to assess verbal working memory. In this test, instead of reading a sentence followed by a letter on each trial, participants see a simple arithmetic problem (such as 'Is $(2 \times 3) + 1 = 7$?') followed by a word. Participants read the problem aloud, respond aloud whether the equation is mathematically correct, and then read the word aloud. After a number of trials, Participants are asked to recall and write down as many of the words as they can in the correct serial order.

Results

RAVEN'S

For both phase 1 (musicians: mean = 27.6, SD = 4.2; non-musicians: mean = 25.7, SD = 3.9) and phase 2 (musicians: mean = 25.7, SD = 7.9; non-musicians: mean = 28.3, SD = 5.2) *t*-tests revealed no significant difference between the Raven's scores for musicians and non-musicians ($p > .05$ for both). To this should be added the result of our selection of participants that equated the two groups on SAT scores and GPAs. Among these results, we see no reason to suppose that the two groups of participants differed on standard measures of aptitude or achievement.

LONG-TERM VERBAL MEMORY

For the RAVLT, one-tailed *t*-tests were used because previous research has shown an advantage in verbal memory for musicians. The present results reveal significant differences between musicians and non-musicians (see Figures 1 and 2). In phase 1, the largest difference was seen when combining participants' performance for the first five trials (musicians: mean = 60.7, SD = 7.2; non-musicians: mean = 53.0, SD = 5.7; $t(24) = 3.17$, $p = 0.004$). These differences disappeared with articulatory suppression in phase 2 (musicians: mean = 55.3, SD = 8.8; non-musicians:

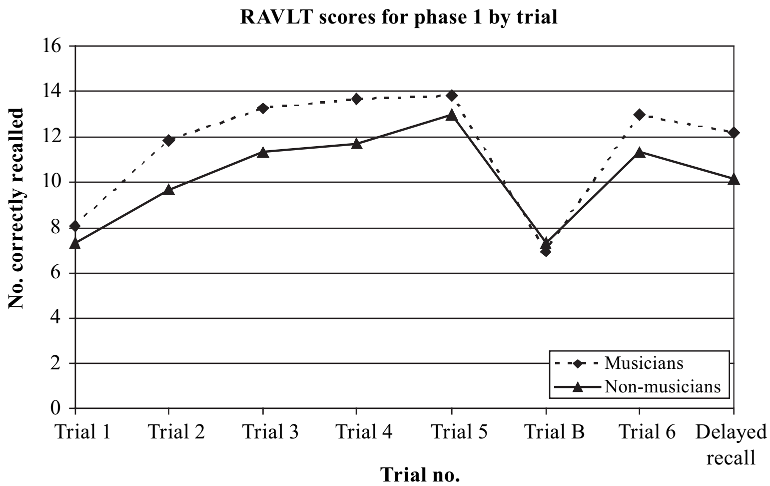

FIGURE 1 *Shows performance of musicians and non-musicians on the RAVLT during phase 1. Overall, musicians perform better on this task.*

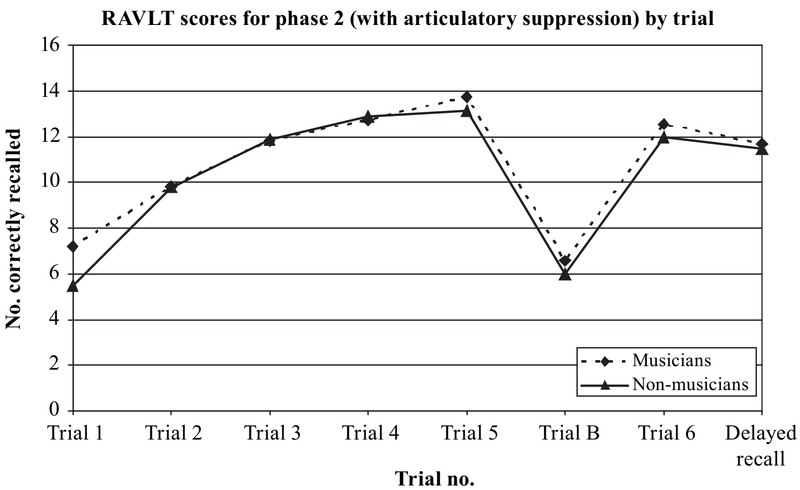

FIGURE 2 *Shows performance of musicians and non-musicians on the RAVLT during phase 2 in which articulatory suppression was introduced. With this manipulation, there is no longer a difference between musicians and non-musicians.*

mean = 53.1, SD = 4.7; $t(19) = 1.19$, $p = 0.31$). The RAVLT also includes an index of long-term memory that results from a delayed recall test. There was a difference in this long-term index between groups (musicians: mean = 12.2, SD = 2.9; non-musicians: mean = 10.1, SD = 2.8; $t(24) = 2.10$, $p = 0.04$) in phase 1, but this difference was not present with the introduction of articulatory suppression in phase 2 (musicians: mean = 11.7, SD = 2.7; non-musicians: mean = 11.4, SD = 1.9; $t(19) = 0.84$, $p = 0.41$). The results of phase 1 show that musical skill is related to verbal memory performance. The fact that this superior performance for musicians is erased by the introduction of articulatory suppression raises a hypothesis about the mechanism that results in superior verbal memory performance for the musicians. Trained musicians appear to be making better use of rehearsal strategies for the verbal material.

VERBAL WORKING MEMORY

Reading span

A marginally significant difference between musicians and non-musicians was revealed by *t*-tests (one-tailed) ($t(19) = 1.78$, $p = 0.08$), with musicians scoring higher (mean = 34.6, SD = 7.5) than non-musicians (mean = 29.67, SD = 8.3). One of the musicians had difficulty with the reading span task, having an absolute score of 0. If this subject is removed from the analysis, then the difference between musicians and non-musicians becomes significant ($t(18) = 2.60$, $p = 0.01$).

Operation span

A significant difference between musicians and non-musicians was revealed by *t*-tests (one-tailed) ($t(19) = 2.86$, $p = 0.01$), with musicians scoring higher (mean = 32.6, SD = 6.5) than non-musicians (mean = 23.0, SD = 7.8).

Thus, the two working memory tasks, taken together, point toward a difference in verbal working memory capacity between musicians and non-musicians.

Discussion

The results from the present experiment are consistent with a number of previous studies and therefore strengthen the claim that verbal memory skills are better for skilled musicians than non-musicians. Specifically, we report an advantage for musicians in a test of verbal memory in phase 1 of the experiment. In phase 2, articulatory suppression was introduced and the difference between groups was no longer reliable. Additionally, we found a greater verbal working memory capacity for musicians. Together, these results provide new evidence that verbal rehearsal mechanisms are contributing to a verbal memory advantage that accompanies skill in music.

Other researchers have suggested that musical training affects non-musical verbal abilities because musical training aids in the development of the auditory cortex and related areas (Brandler and Rammsayer, 2003; Chan et al., 1998; Helmbold et al., 2005; Ho et al., 2003; Ohnishi et al., 2001; Schlaug et al., 1995a). Specifically, there are reports of an increased volume of the planum temporale (Schlaug et al., 1995a) and greater left-sided lateralization or more left-hemisphere activation during a listening task (Ohnishi et al., 2001). These studies suggest that there may be a relationship between the structural differences in musicians' brains and verbal memory processes in that verbal memory, both long-term and short-term, makes use of left-hemisphere structures. What we have found in the present study is that the behavioral outcomes associated with verbal memory may be a result of enhanced use of verbal rehearsal processes both to store information temporarily in working memory and to aid in the creation of longer-term traces of that information. The inference about rehearsal comes from the leveling effect that articulatory suppression has on the verbal memory advantage shown by musicians. In turn, then, it may be that the structural brain differences that have been documented between musicians and non-musicians may reflect an enhanced development of rehearsal strategies that mediates better memory performance.

What of causation? That is, is it musical training that results in enhanced use of rehearsal, or is it that people who become musicians are somehow a self-selected sample of the population with enhanced cognitive skill in a wider range of tasks. Our study provided a good match between musicians and non-musicians on at least gross measures of cognitive skill, including aptitude and achievement measures, and still we found verbal memory differences. So, if musicians are a more highly self-selected sample, they are not so on all cognitive measures. Also, correlational evidence of the type found by Jakobsen et al. (2003) suggests a direct relation between amount of musical training and increases in verbal memory. If musicians just happen to have greater verbal memory abilities then one would not expect more musical training to necessarily lead to greater increases in verbal memory. Likewise, findings by Schlaug et al. (1995a, 1995b) showing that certain structural differences in the brain depend upon the age in which training begins suggest that musical training is responsible for altering brain morphology, which likely leads to subsequent behavioral correlates.

While it is impossible from this single study to infer a causal relationship between musical training and the verbal memory advantage, a growing number of studies, when taken together, are beginning to provide evidence for a causal link. For example, one might claim that it is a pre-existing verbal memory advantage among musicians that biases this group toward taking music lessons, rather than the training itself being the vehicle underlying verbal-memory improvement. However, a piece of evidence against this possibility comes from the training studies described earlier. These training studies, using a randomized-assignment, pre-test and post-test design showed differences in verbal memory specific to a musical training intervention. Additionally, a recent study by Norton et al. (2005) is beginning to answer the question of whether the structural brain differences reported between musicians and non-musicians might already exist in children who are more likely to begin and ultimately continue with musical training. In this study, the authors compared beginning musicians aged five to seven years to their non-musician peers and found no pre-existing neural, cognitive or motor differences. This study is part of an ongoing within-subjects longitudinal study that will be crucial in determining the causal link between musical training, cognitive skills and brain morphology/function. Our own results challenge training studies of this sort to include detailed measures of verbal memory among the outcome measures in that it is now becoming clearer that verbal memory is one of the sequelae to advanced musical skill.

Besides the evidence supporting greater development and/or reliance on left-hemisphere structures related to musicianship, a number of studies report an improvement of spatial skills as well (Bilhartz et al., 1999; Costa-Giomi, 1999; Drake and Palmer, 2000; Gaser and Schlaug, 2003; Hassler et al., 1985; Leng et al., 1990; Rauscher and Zupan, 2000; Rauscher et al., 1995). Probably the most commonly discussed phenomenon of this sort has been the Mozart Effect. Rauscher and colleagues (1993) showed that after just 10 minutes of listening to a Mozart sonata, participants performed better on three separate spatial IQ tasks as compared to controls who were listening to a relaxation tape or silence in the same 10-minute period. A number of follow-up studies have extended the original finding. The general consensus about this line of research is that improved performance on cognitive tasks does not result from listening to a particular type of music, or even to music specifically. Rather, enhancing one's mood or arousal before performing a cognitive task will improve performance (Chabris et al., 1999; Schellenberg, 2005).

Despite the controversy about the Mozart Effect, other studies that focused on musical training rather than simply listening to music have shown improvement in spatial ability related to training. Bilhartz et al., (1999) performed a training study finding that out of all of the subtests (including ones measuring both verbal and visual skills), the only test to show a significant difference (with the musically trained group performing better) was the bead memory task, which is a visual-spatial task in which participants have to remember the temporal order of objects. Other visual-spatial tasks that did not involve ordering did not show significant effects, and neither did any verbal task. Rauscher and Zupan (2000) performed a similar training study. After just four months of training, the experimental group performed better at spatial tasks, and the difference was even larger after eight months. A control test on pictorial memory (a visual, but not spatial task) did not yield a difference between the groups. In a third keyboard training study, Costa-Giomi (1999) targeted children aged nine to 12 years from low-income families to participate for three years of lessons. Her impetus stemmed from the fact that most studies of musical effects on cognition have focused on the typical upper-middle-class musician, with less attention to lower-income children. The experimental group showed a larger increase in spatial reasoning skills, but there were no differences found in verbal or quantitative skills.

This review suggests that the adult cross-sectional studies are more consistent in finding a difference in verbal memory between musicians and non-musicians, while the training studies on children are less uniform in this finding and overall seem to suggest that spatial skills are enhanced with musical training. It is possible that over time and through musical training, shifts occur in brain organization and function that lead to the integration of language areas in musical processing. This may be why the present study and others that compare adult musicians and non-musicians tend to show a verbal memory advantage, while the positive effects reported from training studies involving a few years of training in children predominate in the spatial-temporal domain.

A number of issues still remain unsettled when considering the relation between musical training and cognition. It is hoped that the present work will help clarify this relation by providing more evidence that musical training affects verbal long-term and working memory and showing that enhanced verbal rehearsal mechanisms are likely responsible for musicians' verbal memory advantage.

ACKNOWLEDGEMENT

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NOTES

1. The RAVLT is commonly used as a measure of a person's ability to encode, consolidate, store, and retrieve verbal information. This has led to its use as a sensitive test of verbal learning and memory (see Schmidt, 1996 for a review; see Yamashita et al., 2005 for an example of the RAVLT used with schizophrenia patients).
2. Freshman = year 1 of undergraduate program, sophomore = year 2, junior = year 3, senior = year 4, BA = completed a 4-year degree in the arts, BS completed a 4-year degree in the sciences.

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