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# *The effect of piano lessons on the vocabulary and verbal sequencing skills of primary grade students*

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**ABSTRACT** A number of studies have reported positive associations between music experience and increased abilities in non-musical (e.g., linguistic, mathematical, and spatial) domains in children. These transfer effects continue to be probed using a variety of experimental designs. The major aim of this quasi-experimental study was to examine the effects of a scaffolded music instruction program on the vocabulary and verbal sequencing skills of two cohorts of second-grade students. One group ( $n = 46$ ) studied piano formally for a period of three consecutive years as part of a comprehensive instructional intervention program. The second group ( $n = 57$ ) had no exposure to music lessons, either in school programs or private study. Both groups were assessed on two subtests from the Structure of Intellect (SOI) measure. Results revealed that the experimental group had significantly better vocabulary and verbal sequencing scores at post-test than did the control group. Data from this study will help to clarify the role of music study on cognition and shed light on the question of the potential of music to enhance school performance in language and literacy.

**KEYWORDS:** *language development, literacy skills, music cognition, music training, positive transfer*

A body of research focused around the idea that interaction with music, either through targeted listening experiences or formal lesson instruction, can improve certain cognitive skills in children and adults is steadily accruing (Barwick, Valentine, West, & Wilding, 1989; Bilharz, Bruhn, & Olson, 2000; Chan, Ho, & Cheung, 1998; Costa-Giomi, 1999; Črnčec, Wilson, & Prior, 2006a, 2006b; Douglas & Willatts, 1994; Gardiner, Fox, Knowles, & Jeffrey, 1996; Graziano, Peterson, & Shaw, 1999; Gromko & Poorman, 1998a, 1998b; Hassler, Birbaumer, & Feil, 1985; Helmhold, Rammsayer, & Altenmüller, 2005; Hetland, 2000a, 2000b; Ho, Cheung, & Chan, 2003; Hurwitz, Wolff, Bortnick, & Kokas, 1975; Rauscher & Shaw, 1998; Rauscher, Shaw, & Ky, 1993, 1995; Rauscher & Zupan, 2000; Schellenberg, 2003, 2004, 2005, 2006; Standley & Hughes, 1997). This research is tied to a larger pattern of earlier findings that established the positive role of enriched environments in enhancing overall cognitive development (Diamond, Krech, & Rosenzweig, 1966; Greenough, Volkmar, & Juraska, 1973; Krech, Rosenzweig, & Bennett, 1960). In the case of

music, beneficial cognitive effects have been conceptualized in two ways: passive enhancement and active transfer. The first involves a reactive approach, where passive music listening assists learning, resulting in short-term benefits in non-musical domains. In two widely cited studies (Rauscher et al., 1993, 1995), college students who listened to 10 minutes of music composed by Mozart demonstrated short-term improvements in specific spatial-temporal tasks. Subsequent research failed to support the hypothesis that exposure to short durations of music can have a powerful effect on overall cognition (Carstens, Huskins, & Hounshell, 1995; Črnčec, Wilson, & Prior, 2006b; Kenealy & Monsef, 1994; Nantais & Schellenberg, 1999; Rideout & Taylor, 1997; Stough, Kerkin, Bates, & Mangan, 1994, although see Ivanov & Geake, 2003, Jaušovec, Jaušovec, & Gerlič, 2006). Rather, the apparent benefits of listening to music may result, for example, from differences in mood and arousal induced by the testing conditions (Chabris, 1999; Newman et al., 1995; Steele, Ball, & Runk, 1997; Steele, Bass, & Crook, 1999; Thompson, Schellenberg, & Husain, 2001).

This second line of research involves long-term effects of formal training in music on overall cognition. The cognitive implications of taking music lessons are distinct from the short-term effects of music listening (Schellenberg, 2003). For example, whereas transient effects of music listening on spatial abilities are thought to be instances of hemispheric priming, beneficial effects of music lessons on non-musical abilities are better classified as active transfer effects (Rauscher et al., 1993, 1995; Shaw, 2000). That is, training in one domain – in this case music – transfers over to certain skill sets found in other domains. Children, in particular, have been used in studies of specific classifications testing transfer effects. Their brains are generally more plastic and readily modified by the interaction of an enriched environment and behavioral experiences (Dawson, Ashman, & Carver, 2000; Ho et al., 2003; Norton et al., 2005; Pantev, Oostenveld, Engelien, Ross, Roberts, & Manfred, 1998; Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Takeuchi & Hulse, 1993; Taylor & Alden, 1997).

### *Music-enhanced environments and the promotion of literacy*

Music and literacy are compatible, interdependent symbol systems that share content and process elements, organizational principles, and expressive qualities. Because of this, the domain of literacy presents a rich opportunity to examine the effect of music-enhanced instruction. Several parallels have been noted between coding language and coding music (Hansen & Bernstorf, 2002; Wiggins, 2007). First, both music and language are major and frequent forms of communication for children. A sound, syntax, and semantic progression are present in each, and composition in both forms has traditionally required the musician or reader/writer to organize from established rules to communicate meaning. When students are asked to interpret what textual passages mean, they are likely to call upon stored syntactic and semantic strategies they have internalized to make some kind of meaning out of words. Included in these strategies are decoding, word attack, and comprehension skills. There is an existing linguistic infrastructure for the student to access. Likewise in mediated musical exchange, units, including pitch, timbre, texture, line, and form convey meaning and, just as in written text, meaning can be constructed by students using words, phrases, and sentences. Like

text, music is also read from left to right and top to bottom (Lloyd, 1978). These same parallels have been identified by Hansen, Bernstorf, and Stuber (2004) who noted similar code-breaking strategies required for both music and literacy. They also suggest that dimensions of reading, such as phonological awareness, phonemic awareness, language reception, and fluency have counterparts in music learning and performance.

These skills are linked to the human auditory system, itself a powerful influence in the learning-to-read skill acquisition. Auditory attention and sound discrimination proficiency bolster the quality of children's overall attention spans and generally are among the first of the sequential skills a child must master to attain reading expertise. Because children who are immersed in music-enhanced environments may develop more acute auditory response characteristics, including sensitivity to levels of tone production, perception of rhythmic change, and recognition of timbre differences, it is plausible these skills may reach into extra-musical areas such as reading (Piro, 1982).

Auditory attention skills in children were studied by Gomes, Molholm, Christodoulou, Ritter, and Cowan (2000). They separated these attention skills into four components: arousal, orienting, selective allocation, and sustained attention. One of their findings considered the development of what they labeled a 'self-regulatory system' on attention and the relationship of this function to the frontal lobe. They suggested that:

selective and sustained attention is influenced by listening strategies, motivation, task experience, and the ability to disregard or inhibit processing of certain information. These higher-order processes are aspects of the functional system involved with self-regulation and planning of goal-directed behavior, which have been shown to develop through childhood. (2000, p. 116)

Learning to listen selectively is a by-product of music training, especially in children, and, thus, may assist in developing attentional strategies utilized in both music and literacy contexts.

Trainor, Shahin, and Roberts (2003) studied 4- to 5-year-old children with musical experience and adult musicians to probe the effect of music training on the auditory cortex. For both musically experienced children and adults, the P2-evoked response was larger than in non-musicians. The researchers framed these results in the context that underscored the neuroplasticity potential of P2 and that effects of musical experience can be seen early in development. In another experiment, Anvari, Trainor, Woodside, and Levy (2002) examined musical skills, phonological processing, and early reading ability in 100 pre-school children. In this experimental population, music skills were found to correlate significantly with both phonological awareness and reading development.

### *Music instruction and reading and language performance in children*

Several studies have examined the effects of music involvement on reading ability (Barwick et al., 1989; McMullen & Saffran, 2004). The connection between music and reading has its origin in work on differential processing capacities of the cerebral hemispheres. Several studies have examined the relationship among laterality

patterns, cognitive function, and talent domain experience (Johnson, 1977; Morais, Peretz, & Gudanski, 1982; Piro, 1993a, 1993b; Zatorre, 1979, 1984). In a widely reported study, Bever and Chiarello (1974) found that trained adult musicians processed certain types of music stimuli with their left-hemisphere as opposed to right-hemisphere processing of the same stimuli by musically naive subjects. Prior to this it was generally believed that those perceptual skills required for music processing were right-hemisphere superior. The idea that processing mechanisms for language and music could coexist in the left-hemisphere led some researchers to speculate that inter-hemispheric music processing may be dependent upon music experience and musical sophistication. This set the stage for a line of research hypothesizing that cognitive processes normally associated with music shared neural networks with other mental functions, suggesting that 'centers in the brain are proximal and overlapping and hence linked, rather than being entirely distinct as was predicted by modular theories of the mind' (Hetland, 2000a, p. 180). Because neural response to music is a widely distributed system within the brain, including areas for pitch height, pitch chroma, and timbre in the bilateral auditory cortex, pitch intervals and sound sequences in the planum temporale area, and melody contour in the right superior temporal gyrus, it would be reasonable to expect that some processing networks for music and language behaviors, namely reading, located in both hemispheres of the brain would overlap (Koelsch & Siebel, 2005; Peretz & Zatorre, 2005).

Hurwitz, Wolff, Bortnick, and Kolas (1975) studied the effects of early music training on reading competence by matching two groups of first-grade children, one of which received music training using a Kodály-based curriculum and the other of which received no musical training. Kodály-based curriculum places special emphasis on the musical skill of singing and growth of sequential skills that develop music literacy. The training also used the solfège technique, which assigns syllables to steps or degrees of the diatonic scale. Results of the study demonstrated that children receiving music instruction performed better on reading tests than students not receiving the instruction. Further, this enhanced reading ability was found to continue beyond the first-grade level when the music program continued (Nierman, 1996). Kelley (1981) studied 62 first graders who were divided into one of three groups receiving: (1) Orff Schulwerk-based instruction that involved both vocal and instrumental music learning; (2) visual art instruction; and (3) no music or visual art instruction. At the conclusion of the instruction the researcher found that the group receiving the Orff treatment had significantly better performance on the oral reading sections of the Botel Reading Milestones Test than the other two groups (Nierman, 1996). In another study on children diagnosed with dyslexia, exposure to rhythm-based music training was found to improve both phonemic awareness and spelling skills (Overy, 2000, 2003). Other research (Anvari et al., 2002; Barwick et al., 1989; Standley & Hughes, 1997) has examined the role of music training on the development of phonological awareness and early reading ability in children under the age of 10 and found that music proficiency enhanced such skills as phonological awareness, reading, and writing development, suggesting that both linguistic and non-linguistic general auditory mechanisms are implicated in the process of reading.

## *The present study*

The present study is one of the few that examines the role of long-term music lessons on two targeted reading skills in US elementary school students. The database from studies probing the relationship between reading ability and music instruction is less extensive and conclusive than, for example, studies linking spatial skills and music learning. In commenting on the general pattern of findings of the role of music as a catalyst for improving reading and language competence, Rauscher (2003) suggests that 'it is premature to conclude that music instruction affects reading ability', calling the evidence that music instruction supports enhanced reading ability 'equivocal' (p. 2). One of the objectives of our study was to add to the growing but still sparse database on the role of music lessons in the development of language skills (Hetland, 2000a). Although the effect of music on overall language skills has been a topic of continuing empirical interest, the present study takes the somewhat novel approach of targeting two specific reading subskills and examining these in relation to their enhancement by piano training. These two skills – vocabulary and verbal sequencing – are cornerstone components in the continuum of literacy development and a window into the subsequent successful acquisition of proficient reading and language skills such as decoding and reading comprehension (Bornstein, Haynes, & Painter, 1997; Nash & Snowling, 2006; Oullette, 2006; Richman & Lindgren, 1980). In fact, in a recent US report on national reading skills (National Center for Education Statistics, 2005), fourth graders were tested on such vocabulary-and sequencing-related skills as recognizing meanings of specialized vocabulary, identifying embedded text detail, and recognizing literal information from text attesting to the importance of both literacy skills.

Given high local and national priorities and substantial investment attached to reading by both schools and society, educators have incorporated a variety of approaches, including music, in their teaching practice in continuing efforts to improve reading achievement in children (Deasy, 2002). This study could provide support for the efficacy of such practice. We hypothesized that children who have received keyboard instruction as part of a scaffolded music curriculum would demonstrate significantly better performance on measures of vocabulary and verbal sequencing than students who did not receive keyboard instruction.

## *Method*

### PARTICIPANTS

The study employed a quasi-experimental design. Participants in both treatment and control groups attended two large public elementary schools found in the same middle-class area of New York City. Participants in the treatment group attended a school that offered music instruction for all students as part of a uniform curriculum, and participants in the control group attended a school that did not offer similar music instruction. Both school sites were located in the same geographic vicinity and, as shown in Table 1, had similar demographic characteristics. When differences in demographics did exist between the two schools (e.g., reading scores, median household income), the control school tended to have an advantage.

TABLE 1 *Demographic and sample selection data for participants and schools*

Variable	Treatment school	Control school
Gender		
Male	16	24
Female	29	33
Race/ethnicity***		
Asian	7%	5%
African American	2%	2%
Hispanic	44%	47%
White	47%	46%
Characteristic	Treatment school	Control school
Median household income	\$40,329*	\$47,574*
Median household net worth	\$34,182*	\$40,362*
Yearly per student expenditure	\$11,527***	\$9,902***
Title I school (receives federal assistance)	Yes***	No***
Fully licensed teachers	100%***	95.7%***
Attendance rates	92.8%***	92.9%***
Percentage of children receiving free lunch	57.1%***	48.7%***
Reading score (mean, 2005)	652/800***	665/800***
Percentage meeting city and statewide English Language Arts standards	63.7%**	71.8%**

Note: One child in the treatment group did not list their gender.

\*Source: US Census Bureau.

\*\*Source: New York State Department of Education.

\*\*\*Source: New York City Public Schools.

Because the experimental group school includes music instruction for students as part of the general curriculum while the control group school does not, this naturally occurring situation made possible a logical comparison between these two groups. Because students are zoned to each school according to the 'catchment area' of their homes, parents do not get to decide which of the two public schools to send their children to. When the study began, the cohort of children receiving music lessons ( $n = 46$ ) was about to commence their third year of instruction. This cohort consisted of second-grade children. No tests of music proficiency, general intelligence or academic achievement were required of any child to participate in the music program. Music lessons were offered as part of the uniform curriculum. Children attending the control school ( $n = 57$ ) received no formal musical training on any musical instrument and had never taken music lessons as part of their general school curriculum or in private study.

#### SCHOOLS' LITERACY PROGRAMS

Both schools follow comprehensive balanced literacy programs – that is, programs integrating skills of reading, writing, speaking, and listening. Both schools assign full-time literacy coaches to primary grade teachers who work on developing classroom instructional skills. Both schools also make use of extended literacy blocks where

lengthy periods of the day are dedicated to developing key literacy skills including reading and writing. For example, during these literacy blocks, children might participate in exercises in phonological awareness in which they are taught to aurally discriminate between units of sounds by counting syllables and reciting or listening to nursery rhymes or poems. This might be followed by decoding exercises where these rhymed words are matched and children are asked to identify appropriate rhyming pairs. Teachers in both schools keep running reading records and portfolios of individual student performance and progress to formatively assess these skill sets.

Teachers in both schools receive professional development in the way of coaching and consulting from experts in two well-known design models in education. The treatment school works with the America's Choice Program while the control school works with the Readers and Writers Project. In both programs, grade cohorts of teachers participated in a collaborative coaching model during which they practiced constructing classroom writing workshops where children learned to draft, revise, and publish narrative and expository text. Model classes were also developed where teachers could visit, watch, and learn effective research-based literacy practice. This overall intervention worked to build instructional capacity in both schools, to promote student academic achievement, and to build an overall culture of literacy. At the end of the school year in which the study was conducted, 63.7 percent of students in the treatment school met statewide standards in the English Language Arts test while 71.8 percent of students in the control school met the same standards. Both schools also achieved the Adequate Yearly Progress (AYP) goals as designated under No Child Left Behind (2002) legislation.

#### MATERIALS

All participants in the study were administered two subtests of the Meeker Structure of Intellect (SOI) – Form L. This standardized testing instrument was designed for a large urban school system and has been widely used throughout this school system since the early 1980s to measure discrete intellectual abilities of students from pre-kindergarten to grade 3 (eight to nine years of age). This instrument was selected due to its psychometric properties, general familiarity by school personnel, and usefulness within a population of early childhood students. Roid (1984) factor-analyzed the SOI subtests and found strong evidence for the construct validity of the figural, symbolic, and semantic dimensions of the SOI model. Roid's verification of these three dimensions of cognition is particularly important for the early grades, where the success or failure of instruction may depend on the student's figural/symbolic/semantic strengths and weaknesses.

The first subtest used was *Vocabulary* (Figure 1), which the manual describes as follows: 'This is a general vocabulary test. It screens the ability to comprehend meaning of words and ideas'. For each of the picture items, the examiner says, 'Tell me what this picture is' (points to picture). The child is allowed to respond and the response is recorded as correct or incorrect.

The second subtest was *Verbal Sequencing*. This test screens for the ability to understand order and pattern of extended verbal information and to interpret shapes having equivalent meanings. The examiner reads each item to the child, for example: 'Show me a ball inside a star'. The child is required to point to the set of shapes that depicts the statement that the examiner reads.

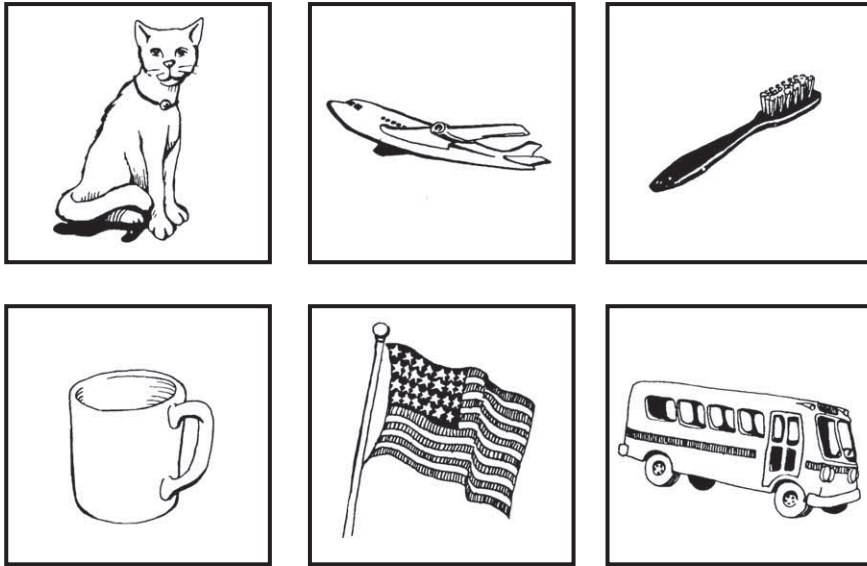


FIGURE 1 *Sample of SOI vocabulary test item.*

Sequencing Verbal Information 1

Show me.....

A BALL INSIDE A STAR

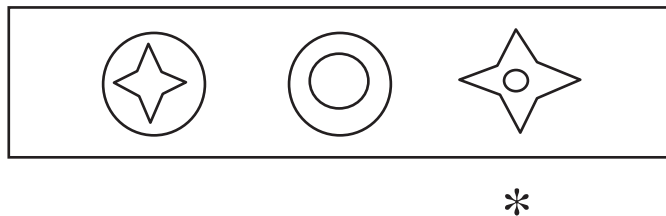


FIGURE 2 *Sample of SOI verbal sequencing test item.*

PROCEDURE

After Institutional Review Board (IRB) and school district approvals were given to conduct the study, letters were sent home to parents asking permission to include their children in the research. Meetings with parents were also held to explain and clarify the nature of the study. All participants were individually pre- and post-tested at the start and close of a standard 10-month school year. Testing for the study was

performed by teaching professionals trained in test administration. The two subtests from the SOI were always administered in the same order and in the same setting by the examiners at both schools. Testing sessions typically lasted 15–20 minutes.

Materials from the Music and the Brain (MATB) project served as the basic music curriculum. This curriculum introduces the student to basic music notation, fingering technique, sight-reading, note and rest values, and other related musical topics. For those subjects in the keyboard group, lessons were provided by the school's trained MATB teachers in a specially equipped music laboratory containing Casio electronic keyboards mounted on child-sized music stands. Additional instructional materials included piano books, teaching manuals, rhythm cards, theory papers, poster-size copies of each page of the books, and CDs. Two instructional periods of 40 to 45 minutes occurred each week. The class presented a sequence of four elements:

1. **Musical concepts:** These include rhythm, pitch, form, tempo, dynamics, notation, harmony, counterpoint, and timbre, and are incorporated throughout music study. The ear training involves singing and rhythmic training and is directly related to the pieces being taught. For example, when students are introduced to a new song, they will clap the rhythms and sing the melody before playing the piece. In this way, these children develop a phonological awareness by clapping rhythms and singing the melody before a song is taught. They might create their own rhymes and then handclap these as well as continuing to practice recognizing pattern repetitions and recreating rhythmic passages which they heard.
2. **Musical warm-up:** Children play a series of warm-ups to strengthen dexterity, to prepare for playing a piece of music, and to reinforce ear training.
3. **Music practice:** Usually half of the class time is spent learning, practicing, and playing the piano. The repertoire is chosen to illustrate musical concepts while developing piano techniques. A new song, written out in musical notation, can be introduced, or a previous lesson continued. Throughout the year many pieces are introduced, including classical music, folk songs from around the world, and children's songs (see Figure 3).
4. **Music creativity:** The final element encourages creativity by allowing children to freely explore the keyboard. Sometimes they are guided into improvising or creating a composition; sometimes they simply 'play'; and sometimes they choose to work on certain pieces in their repertoire. The children regularly perform for one another and are provided the opportunity to perform at larger concerts.

As an example of a lesson, the teacher would initiate the concept of musical directionality. Children are introduced to the idea that music can move up, down, or stay the same. After visualizing these movements and acting them out, children are then given an opportunity to practice and hear this concept on their individual keyboard and headphone. Musical notes are introduced on both large charts in front of the classroom as well as at the keyboard and demonstrated by the teacher. This is followed by a period of guided practice. In addition, children are encouraged to partake in mental rehearsal of actual piano playing without any overt movements, an activity shown to accelerate skill acquisition as well as having the potential to affect cortical organization (Pascual-Leone, 2005). The MATB program was conducted as part of each student's school day experience. It was not implemented after school, during lunchtime or any other 'free' or unassigned period.

## GRAND STAFF

### Right Hand and Left Hand

L.P.L.

The figure displays three systems of musical notation for a grand staff, showing the right-hand (R.H.) and left-hand (L.H.) parts. The notation is in 4/4 time and uses a grand staff with a treble clef for the right hand and a bass clef for the left hand. The first system shows the R.H. part with notes C4, D4, E4, F4, G4, A4, B4, C5, followed by whole notes C5 and C4. The L.H. part consists of rests. The second system shows the R.H. part as rests and the L.H. part with notes C3, B2, A2, G2, F2, E2, D2, C2, followed by whole notes C2 and C3. The third system shows both R.H. and L.H. parts with the same sequences of notes as the first two systems. Fingerings are indicated by numbers 1-5 below the notes.

FIGURE 3 *Sample performance piece from MATB curriculum.*

### *Results*

Before formal data analysis was undertaken, data were examined to determine whether they met the statistical assumptions required for analysis. There were no missing data and data were normally distributed. Four outliers were noted, although analyses were almost identical with and without the outliers. The analyses below do not include the four outliers. Because we expected to compare the experimental group with the control group, Levene's test for equivalence of variances was examined. The test was significant for post-test SOI verbal scores, indicating that the variability in the control group was significantly greater than the variability in the experimental

group. Unequal variances can inflate Type I error rates slightly, so for our analyses, we used a two-tailed alpha level of .01. This is a conservative approach, as it usually requires wildly different variances to substantially increase the chances of a Type 1 error (Keppel & Wickens, 2004). All other assumptions relating to specific statistical tests (e.g., independence of scores for Analysis of Covariance (ANCOVA)) were met. In addition to using a more stringent alpha level, we ran parallel analyses, where we transformed all scores with a square root transformation to make the variability between the experimental and control groups less unequal. The results using transformed scores were not different from the results, presented below, that we obtained using untransformed scores.

As shown in Figure 4, for control group children SOI vocabulary scores rose slightly, from a mean of 15.82 at pre-test to a mean of 16.12 at post-test. Experimental group SOI vocabulary scores rose from a mean of 15.67 at pre-test to a mean of 18.28 at post-test. We conducted an ANCOVA on SOI vocabulary post-test scores, using SOI vocabulary pre-test scores as covariates (Table 2). The difference between covariate-adjusted post-test scores was 2.48 points (SE = .29 points). The

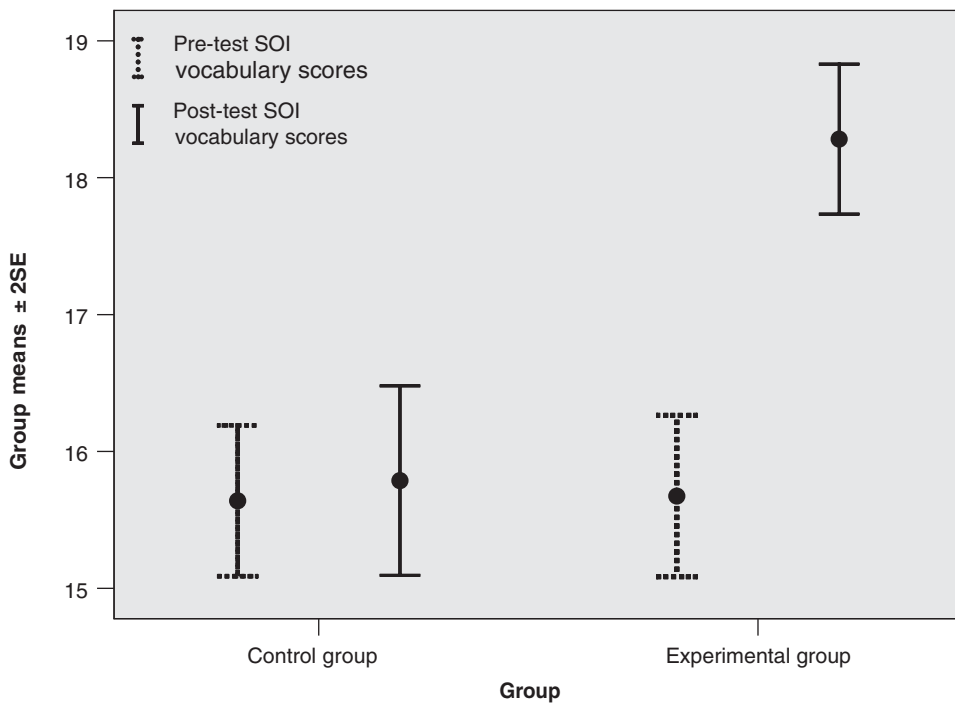


FIGURE 4 Results on vocabulary measure at pre-test and post-test.

TABLE 2 ANCOVA of experimental versus control group changes in the Meeker SOI – Form L

SOI subtest	Experimental		Control		F	$\eta_p^2$	p
	Pre-test	Post-test	Pre-test	Post-test			
Vocabulary	15.67	18.28	15.82	16.12	41.57	.294	<.001
Verbal sequencing	10.89	13.28	10.26	8.84	58.86	.371	<.001

mean post-test SOI vocabulary score of the experimental group was significantly higher than the mean post-test SOI vocabulary score of the control group, controlling for pre-test SOI vocabulary scores  $F(1, 100) = 41.57, p < .001$ . A large effect size was found (partial eta squared = .294).

As indicated in Figure 5, for control group children SOI verbal sequencing scores dropped from a mean of 10.26 at pre-test to a mean of 8.84 at post-test. Experimental group SOI verbal sequencing scores rose from a mean of 10.89 at pre-test to a mean of 13.28 at post-test. The difference between covariate-adjusted post-test scores was 4.34 points (SE = .26 points). ANCOVA revealed that the mean post-test SOI verbal sequencing score of the experimental group was significantly higher than the mean post-test SOI verbal sequencing score of the control group, controlling for pre-test SOI verbal sequencing scores  $F(1, 100) = 58.86, p < .001$ . A large effect size was found (partial eta squared = .371).

In order to examine whether these significant treatment effects might vary by subject sex, we conducted a factorial ANOVA, with group (control versus intervention) and sex (male versus female) as the independent variables for each of the two dependent variables. There were no group by sex interactions for SOI vocabulary scores  $F(1, 98) = .103, p = .748$ , or for SOI verbal sequencing scores  $F(1, 98) = .076, p = .784$ .

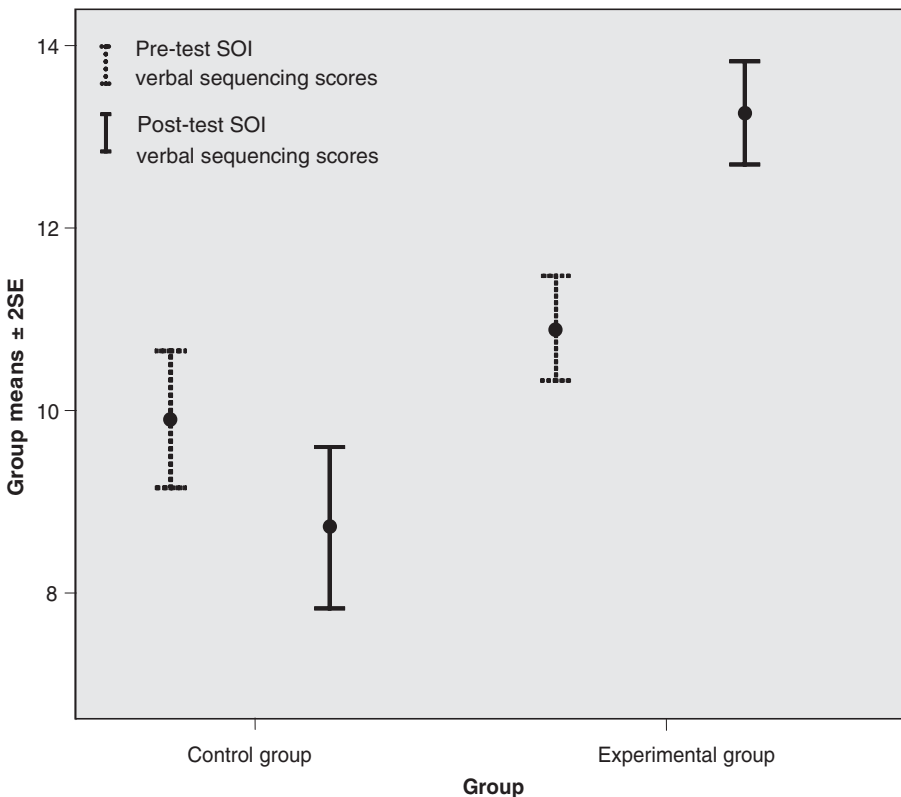


FIGURE 5 Results on verbal sequencing measure at pre-test and post-test.

## *Discussion*

This quasi-experimental study targeted two specific reading skills, vocabulary and verbal sequencing, and examined gains in them among children who experienced three years of scaffolded music instruction. This instruction, experienced twice a week, was delivered parallel with the school's balanced literacy program, which included daily lessons in reading, writing, speaking, and listening. Results showed that on both literacy tasks those children who received three successive years of music training as a part of their general school curriculum outperformed children who received no music training. These findings are consistent with those of similar studies in which children who received musical training displayed superior cognitive performance in comparison to their non-musically-trained peers (Bilharz et al., 2000; Costa-Giomi, 1999; Graziano et al., 1999; Gromko & Poorman, 1998a, 1998b; Hassler et al., 1985; Ho et al., 2003; Rauscher et al., 1997). Further, this study concentrated on discrete areas of vocabulary and verbal sequencing because these were thought to represent two skills sets where music might make particularly robust inroads, especially in children in emergent reading stages.

This issue of fusing music lessons with daily instruction in the content area of reading is an important one. Children in this study are part of a growing cohort of students in the US who continue to experience sizeable doses of literacy learning in the form of extended instructional time blocks (Pressley, Solic, Gaskins, & Collins, 2006). Because of the cognitive complexity of this type of complementary, multi-layered combination of music and literacy instruction, an opportunity may have occurred for children to experience some neurological enhancement, an outcome replicated in other associated empirical studies (Elbert, Pantev, Weinbruch, Rockstroh, & Taub, 1995; Pantev et al., 1998, 2001; Peretz & Zatorre, 2005; Schlaug, Jancke, Huang, Staiger, & Steinmetz, 1995; Schlaug, Jancke, Huang, & Steinmetz, 1995). With the overlap in areas throughout the cortex used to process music and reading, this may be an indication that strengthening neural codes used in managing one could positively affect development of the other (Pantev et al., 1998; Peretz & Zatorre, 2005; Pugh et al., 1996).

In further analyzing overall results, a closer look at outcome patterns for both language subtests may be instructive. Results from the Vocabulary subtest demonstrated that the treatment group made significant pre-/post-test gains, while scores in the control group remained mostly static. In interpreting this result it is helpful to split the term 'vocabulary skills' into separate skill sets that include speaking, writing, reading, and listening, to parallel the structure of the balanced literacy programs offered in both schools (Anderson & Freebody, 1981; Armbruster, Lehr, & Osborn, 2001; Snow, Burns, & Griffin, 1998). One explanation for the between-group difference in vocabulary proficiency may be enhancement of auditory attention skills, the result of intensive and sustained music training. Children in the treatment group were exposed to a great deal of auditory stimulation during their three-year training period, including melodic pitch identification, timbral discrimination, and tonal patterning, and it is likely that these music experiences enhanced aural sensitivities. As in a study of 90 six- to 15-year-old boys with music training who demonstrated significantly better verbal memory than children without such training (Ho et al.,

2003), the longer the training, the better the verbal memory. The control group received no similar auditory stimulation from pre-test to post-test.

In addition, children in the treatment group participated in such exercises as matching various music symbols to their written names, recording vocabulary words that were found in music lyrics studied, and describing musical qualities heard in a composition. They used a developing music vocabulary to verbalize what they were doing (e.g., staff, measure, notes, rests) and studied, recorded, and transferred high-frequency words into multiple contexts. Students were encouraged to use this high-frequency, high-utility vocabulary in 'talking' as well as playing music, and it was hypothesized that these lexical and semantic processes would assist in refining and expanding students' general fund of knowledge (Register, 2001). These children's listening vocabulary may have been particularly affected in a manner absent in the control group because of their lack of a similarly differentiated rich aural environment. Speech and music are, most probably, two of the most frequent auditory events for children, with both containing semantic and syntactic properties that require perceptual expertise in the listener. Both forms also call for the listener to organize from established rules to understand and communicate meaning and may, accordingly, share processing resources (Jentschke, Koelsch, & Friederici, 2005).

As for the second subtest used in the study, that of Verbal Sequencing, this blended linguistic and spatial-visual task demands characteristics. The unique auditory demands of attending to a pitch in aural space and recognizing features such as frequency, duration, rhythm, and timbre have been suggested as closely tied to the development of spatial processing, and this is a recurring issue in studies of music cognition in which advantages in spatial-temporal processing in those children receiving music training have been found (Graziano et al., 1999; Gromko & Poorman, 1998a, 1998b; Hassler et al., 1985; Shaw, 2000). Because making music depends on an understanding of rhythmic and tonal patterns, it was thought that training on an instrument such as a piano, which follows a hierarchically generated and visually linear representation of spatial relationships between pitches as the keyboard ascends or descends from note to note, would serve as a functional visual template of aural patterning and sequencing (Rauscher et al., 1997). This training might develop or enhance global sequencing skills which may account for pre-test to post-test between-group differences on this particular measure and why the treatment group demonstrated score regression from pre-test to post-test. Lloyd (1978) stressed the importance of music in constructing visual sequential memory and in developing an ability to recall music sounds and lyrics long enough to forge some kind of meaning for children. This is evident, for example, if a musical passage contains a repetitive refrain. Children in the treatment group who were involved in music instruction and subsequent performance tended to learn compositions by systematic sequence-repetition and it is this process that may mirror sequential skills in extra-musical arenas such as literacy, hence their solid post-test gains.

As for the regression in this skill experienced by the control group, because verbal sequencing tends to be considered a 'building block' skill in literacy, more practice in it may have occurred during kindergarten and grade 1. By grade 2, children have moved on to learning the language and structure of writing and reading comprehension, and verbal sequencing skills may not be addressed with the same depth and frequency.

For example, in beginning literacy skills in grades kindergarten or 1, students may be asked to describe, list, and sequence events in a story in the order they happened. By grade 2 they may be asked to make decisions about the importance of events and which of these to include and exclude when writing a story that includes characters and dialogue.

To be sure, gains made on both language measures by children in the treatment group could be explained by the intensity of the literacy experience they received both in the music and reading programs coupled with high teacher quality, strong student motivation levels, and parental encouragement. Conversely, those children in the control group may not have been exposed to comparable high-quality literacy instruction that could have also explained the deficit in the verbal sequencing measure. This, coupled with other factors including the lack of auditory enhancement development and the absence of enriched content including music-focused vocabulary instruction, may explain the finding of no pre-/post-test differences in the scores of the control group.

Limitations exist in the study. First, the overall design was quasi-experimental and did not employ random assignment. However, it should be noted that in the treatment group, the school that children attend is not a magnet, special talented or musically 'themed' school requiring any special admissions requirements. It is a zoned neighborhood school that students attend because of where they live. Parents of children attending the school could not have their children opt out of the school's general curriculum that mandates music instruction for all primary grade students. Similarly, children zoned for the control school could only participate in the general curriculum designed for primary grades at that site. In this school, there is no opportunity to receive piano instruction as a value-added 'extra'. While post-test differences in vocabulary and verbal sequencing skills could be a result of variables other than the presence or absence of music instruction, the fact that children attending both schools are demographically similar and are not able to choose which school to attend does reduce the likelihood of a confounding variable accounting for the observed results.

Another limitation is the status of both groups when the research study commenced. When the study began, the treatment group had already experienced two years of piano lessons. However, at pre-test, scores for both control and treatment groups on the vocabulary and verbal sequence tests were nearly identical. This poses an intriguing question. If the children receiving piano instruction already had two years of music involvement, why did they not significantly outscore the musically naïve students on both measures at the outset? Music instruction has been demonstrated to exert cortical changes in certain cognitive areas such as spatial-temporal performance fairly quickly (Bilharz et al., 2000; Rauscher & Zupan, 2000), so why the exception for this study? We propose three factors as possibly contributory to this outcome.

First, children in the treatment group were pre-tested at the beginning of their third year of music instruction, just as they were about to enter second grade. This pre-testing occurred very early on in the school year. It may be the case that because of the absence of any music instruction during a lengthy summer recess, any earlier cortical reorganization experienced by students in the treatment group may have been temporary, a finding reported in other related research (Costa-Giomi, 1999; Rauscher et al., 1993). Another explanation could implicate the duration of music

study. Perhaps two years of training is insufficient to sustain long-term cortical changes, at least in the task areas of vocabulary and verbal sequencing, and longer periods of music involvement are required. In Chan et al. (1998), it was found that at least six years or more of music study resulted in better verbal memory.

Second, reading is a complex cognitive event involving at least as many widely distributed neural systems as music and with many subcomponents (McCandliss, Beck, Sandak, & Perfetti, 2003; McCandliss & Wolmetz, 2004; Pugh et al., 1996; Shaywitz, 2003; Shaywitz et al., 2002). When speaking of transfer effects music instruction may exert on reading, many studies have examined some of these sub-components including phonological processing (Anvari et al., 2002, Overy, 2002), spelling (Overy, 2002), and verbal memory (Chan et al, 1998; Ho et al., 2003). These skill sets have all been found to be localized to specific cortical regions. It may be that both vocabulary and verbal sequencing skills (which have been much less probed) are also localized to cortical regions developmentally receptive to enhancement during a specific time period, and that music instruction provided at this time may have facilitated this enhancement. This hypothesis is based on Brown, Martinez, and Parsons's (2006) suggestion that music and language sit side-by-side in the brain and that functional equivalence of homologous regions for music and language may 'assume that these homologous cortical regions process complementary facets of a single function' (p. 2792). These researchers suggest that, because music and language rely on combinatorial operations to generate meaningful sound structures, they may share overlapping neural resources when processing specific stimuli. In a recent functional Magnetic Resonance Imaging (fMRI) study (Rodd, Davis, & Johnsrude, 2005), selected vocabulary word-meaning tasks activated bilateral frontal gyri and temporal cortex – the same areas some music tasks bilaterally trigger. It may be that a given cortical region and its homologue can be specialized for processing different functions, such as music and language, and are both susceptible for mutual enhancement given the appropriate conditions, forming what Brown et al. (2006) identify as an 'interface area' (p. 2801).

A third explanation involves auxiliary neurocognitive events contributing to morphological change in the brain during a critical developmental time period. During the course of their third year of music lessons, the treatment cohort was in second grade and approaching the age of seven. There is evidence that there are significant spurts of brain growth and gray matter distribution around this developmental period (Epstein, 1986; Fischer & Rose, 1998; Gale, O'Callaghan, Godfrey, Law, & Martyn, 2004; Ounsted, Moar, & Scott, 1988; Sowell, Thompson, & Toga, 2004, although see Shahin, Roberts, & Trainor, 2004). In a study of language development in children around the age span of seven, neuroplasticity was discovered with progressive participation in linguistic function by both left- and right-hemispheres (Szaflarski et al., 2006). Also, some studies suggest that it is not until seven years of age that implicit knowledge of more sophisticated music concepts such as scales and harmonic discrimination is developed (Costa-Giomi, 1994; Trainor & Trehub, 1992, 1994).

Because music training for the treatment group was scaffolded in difficulty throughout three years of instruction including not only piano performance but, progressively, music notation study, singing theory, ear training, and music

appreciation, their third year of instruction could have been particularly challenging. The combinatory quality of this multifaceted music instruction coupled with more intensive literacy experiences may have helped students cross a neurological threshold through the networking of visual, auditory, kinesthetic, and tactile systems. This event may have come precisely at a stage where developmental changes in the brain were occurring as well, accounting for the surge demonstrated in the treatment but not the control group (Pascual-Leone, 2005). The subsequent force of this multisensory synthesis, fusing an intensive literacy program with scaffolded music instruction, might have worked interdependently so that the learning of one mutually supported and strengthened the learning of the other. This, in turn, may relate conceptually to what has been identified as superadditivity, or the cumulative benefits of the ability of the brain to integrate information from different senses for cognitive growth (Laurienti, Perrault, Stanford, Wallace, & Stein, 2005; Stanford & Stein, 2007; Stein & Meredith, 1993). Further, these cumulative effects of learning integration may connect with what Fischer and Rose (2001) call 'webs of development', in which students construct multiple strands of sight and sound stimuli in their 'web', with each sensory category 'contributing to the emergence of more complex skills along a strand' (p. 8) that increases across instructional episodes. All of this adds a compelling layer of meaning to the experimental outcomes, perhaps signaling that decisions on 'when' to teach are at least as important as 'what' to teach when probing differential neural pathways and investigating their associative cognitive substrates.

The examination of the role of music on cognition has proven to be a provocative and challenging topic in neuroscience. Studies continuing to investigate the association between music training and cognitive enhancement eventually may confirm a solid link between the two (Tallal & Gaab, 2006). If more can be understood about particular cerebral substrates involved with music cognition – where they are, what specific music training relates to them, and if the timing of this training is relevant – then knowledge about other higher-order functions may be clarified and this will enrich the understanding of the scope of human learning. Study of how music may also assist cognitive development will help education practitioners go beyond the sometimes hazy and ill-defined 'music makes you smarter' claims and provide careful and credible instructional approaches that use the rich and complex conceptual structure of music and its transfer to other cognitive areas. Access to this information may encourage both educators and neuroscientists to collaborate on the design of new curricular options framed by fundamental concepts known to be shared by music and accompanying disciplines such as mathematics and literacy (Posner & Rothbard, 2005). This, in turn, can demonstrate how brain research can better serve the broader needs of education and provide a deeper understanding of both human intellectual function and neurocognition.

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