Benefits of a classroom based instrumental music program on verbal memory of primary school children: a longitudinal study

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Abstract

Previous research has demonstrated a benefit of music training on a number of cognitive functions including verbal memory performance. The impact of school-based music programs on memory processes is however relatively unknown. The current study explored the effect of increasing frequency and intensity of classroom-based instrumental training program on verbal and visual memory across a two year period. Data from 142 participants were analysed: 82 (41 female (F), 41 male (M); mean age 8.62 years) allocated to the intensive strings music training program and 68 (37F, 31M; mean age 8.79 years) allocated to the control group (usual music classes). The Children's Memory Scale was used to test digit span, verbal learning and immediate and delayed verbal memory. Immediate visual recall was tested using the Benton Visual Designs test. Mixed model ANOVAs revealed that students receiving the intensive music training program exhibited significantly better learning and immediate recall for verbal information, after approximately one year, but not two years, after implementation of the program than did controls. No such benefit was observed following one year of a similarly novel juggling program in a sub-set of the sample. As anticipated, the intensive music training had no effect on visual memory, although an improvement in visual perceptual ability and digit span recall was observed in the first year also. The current findings have implications for educational programs (such as literacy training) which may benefit from transient improvements in verbal memory.

Keywords: group-based; string pedagogy; music education; verbal memory; cognitive functioning.

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Introduction

Musicians have been found to demonstrate enhanced cognitive and psychosocial functioning when compared with non-musicians, demonstrating superior verbal memory ability (Chan, Ho, & Cheung, 1998; Costa-Giomi, 2004; Ho, Cheung, & Chan, 2003; Kilgour et al., 2000; Jakobson, Kilgour & Cuddy, 2003), pitch processing skills (Pantev et al., 1998), temporal processing skills (Jacobson et al., 2003), and self-esteem (Hietolahti-Ansten & Kalliopuska, 1990). Some of the most convincing evidence for the non-musical benefits of music training has been obtained in studies of verbal memory. The construct of verbal memory consists of acquisition (or learning), immediate recall and delayed recall of verbal or auditory information. Adults with extensive formal music training (up to15 years) and musicians (with at least 14 years of training) have shown significantly better verbal recall than non-musicians across a variety of measures of verbal ability including word lists, unfamiliar song lyrics (spoken and sung), and vocabulary subtests from aptitude, memory or IQ tests (Brandler & Rammsayer, 2003; Chan, Ho, & Cheung, 1998; Jakobson, Kilgour & Cuddy, 2003; Kilgour, Jakobson, & Cuddy, 2000). Similar effects have been observed in children. Ho, Chan and Cheung (2003) compared children (aged between 6-15 years) who were currently learning an instrument (for a period of 1-5 years) with classmates who had no musical training. The children receiving the music training recalled approximately 20% more words from a 16 word list presented three times than their classmates without music training. They also showed better verbal retention ability across two delayed recognition trials. No benefit was observed in visual memory performance, which was argued to be due to its right temporal lobe localization.

In a follow up longitudinal study one year later, Ho et al. (2003) compared children (from the original cohort) who had since begun or continued their music training for one year with those that had discontinued their music studies at least 9 months prior. Both the beginners and continuing group showed significant improvement in their verbal learning and retention scores whereas there was no change for those that had discontinued their musical training. Interestingly, although the discontinued group did not improve their verbal memory performance, they maintained the verbal memory superiority over non-musicians, implying that the benefits of playing an instrument may be long lasting. Consistent with the previous findings, there was again an absence of significant effects of music training on visual memory. While this study was quasi-experimental in that students had already self-selected into music or non-music training classes at the start of the study, inferences about causality are strengthened by demonstration that the groups were similar on measures of age, educational level, IQ, and parental educational level and income. Similarly, while conclusions from correlational evidence linking musical training and enhanced cognitive or neurophysiological functioning must be drawn with caution, a strong relationship between such measures and years of musical training provide a convincing argument against differences being pre-existing (Münte, Altenmuller & Jäncke, 2002). Superiority in verbal memory in musicians appears also to be associated with the number of years of formal music training (Ho et al., 2003; Jakobson et al., 2003), which implies that musical training underlies the improvement in verbal memory. It is notable, however, that even relatively short periods of engagement with music can have positive effects on cognitive abilities. Young children receiving Suzuki violin lessons demonstrated enhanced general memory and responsiveness to musical sounds after one year of instruction when compared to children who were not having music lessons outside of school. These benefits were noticeable after just four months (Fujioka, Ross, Kakigi, Pantev & Trainor, 2006).

Experimental studies in which participants are randomly allocated to music lessons or control groups nevertheless provide more persuasive evidence of the benefits of music training. For instance, Schellenberg (2004) demonstrated that music lessons significantly enhanced the general intelligence of six-year olds. He randomly assigned 144 six year old Canadians recruited from a community newspaper to one of four groups; keyboard lessons or Kodály voice lessons (experimental groups) and drama or no lessons (control groups). The music and drama lessons were taught in small groups of 6 children, and were of 36 weeks duration. The children receiving the music classes showed a small but significant increase (d=0.35) in full scale IQ when compared with the control groups. The music groups also showed a larger increase on all subtests of a measure of academic achievement (Kaufman Test of Educational Achievement). Music lessons have also been found to benefit self-esteem (Costa-Giomi, 2004). Fourth grade students (N=117) from a low socioeconomic status Canadian population were randomly assigned to individual piano lessons or no formal music training. The students receiving the piano instruction showed significant gains in self-esteem after three years of tuition. Limited experimental evidence has also shown that music training may improve literacy and numeracy skills (Gardiner, Fox, Knowles & Jeffrey, 1996), visual memory (Bilhartz, Bruhn, & Olsen, 2000), and spatial ability (Graziano, Peterson, & Shaw, 1999; Rauscher, 2002).

Research in this area, however, remains limited by its questionable generalizability. For instance, many studies have focussed on highly trained musicians, without exploring other forms of musicianship. A recent study demonstrated however, that non-musicians who reported being highly engaged with music (high frequency of listening to music, strong affective engagement in music) also demonstrated superior verbal memory than non-engaged participants. In addition, studies on children have tended to focus on young children receiving private tuition, and therefore conclusions may not be generalizable to school-based music classes. Nevertheless, the need for research into the value of school-based music education is urgent given its diminishing role in many school curricula. School-based music classes increase access to music education to all children and are more consistent with the recommendations of a recent National Review of Music Education (Department of Education, Science and Training, 2005) in Australia, which highlighted that enhanced quality and accessibility of music education was a priority for students in this country. In particular, many children from geographically or socially disadvantaged areas were missing out on music education altogether. In one of the few experimental studies on the non-music benefits of school-based music training, Gardiner, Fox, Knowles and Jeffrey (1996) demonstrated a significant improvement in literacy and numeracy following a class-based "test arts" program which included the introduction of the Kodály method into Grade 1 classes over 2 years. Students in the arts group initially demonstrated poorer performance on literacy and mathematics tests. However, after 7 months, and again on retesting a year later, children in the arts groups had achieved similar scores as the controls on the reading tests, and had outscored the controls on mathematics. The program was, however, a combination of arts-based activities (visual and musical) and the contribution of music education to the improvements observed cannot be ascertained from these data. In addition, the absence of a separate control group which experienced non-specific features of the arts classes (such as introduction of a new teacher, and relief from usual curriculum) makes it difficult to discount that the improvement could be due to novelty or an increase in attention.

Given the mounting evidence in regards to the non-musical benefits of private music instruction, it would be valuable to examine whether the more accessible and equitable classroom music experience confers benefits in academically relevant measures. The current study explored the effect of a classroom-based strings-based instrumental music training program on visual and verbal learning and memory in primary school age students over a three year period. The program was introduced into a cluster of regional schools as part of their timetabled curriculum. To control for the possibility that any benefits may have resulted from introduction of a novel arts-based program (see Schellenberg, 2004), the effects of one year of a novel juggling program were also observed on a sub-set of students from each condition. It was hypothesized that the increased quality and frequency of the strings training program would yield improved verbal learning and memory. In contrast, it was hypothesized that significant improvements in verbal learning and memory scores would not be observed with either standard music classes, nor with the introduction of the juggling program. Finally, it was expected that the facilitation would be limited to verbal memory performance, and no significant effects would be observed with the visual memory task.

Method

Participants

Students (N=151) were recruited from nine regional state primary schools, with 89 (45F, 44M) allocated to the intensive music program and 62 allocated to the control group (33F, 29M). Missing data was distributed fairly evenly across groups and genders, and omission of these cases as well as several age outliers yielded a sample of 142 participants, with 82 (41F, 41M; mean age 8.62 years) allocated to the intensive music program and 68 (37F, 31M; mean age 8.79 years) allocated to the control group (see Table 1). All schools expressed an interest in participating in the full music program although allocation to the new music training program required an agreement from the school that they possessed or could contribute towards the purchase of necessary resources (such as instruments) for the program. Allocation to the treatment groups was therefore not random, although the groups were similar at baseline on all demographics examined except age (see Table 1). (A delay in testing all the control schools at baseline due to unanticipated timetabling constraints of the schools meant that control participants were marginally older (approximately 2 months) than music program participants.)

Following the main study, a subset of the sample (n=44) was followed for an additional year. Nested within schools, 24 (9F, 15M) participants continued to receive their standard music classes (same as controls in main study) while 20 (16F, 4M) participants (previously controls in the main study) were allocated to a juggling program.

Measures

Each participant completed a personal details form to record age, gender, favourite leisure activities and informal and formal music training. They also completed the Word Pairs subtest and Digit Span Forward subtest of The Children's Memory Scale (CMS; Cohen, 1997) and Benton's Visual Retention Test (BVRT; Sivan, 1992). (This research formed part of a larger study (see also Rickard, Appelman, James, Murphy, Gill & Bambrick, 2010), and other measures relating to that aim included the Culture-Free Self-Esteem Inventory-Third Edition (CFSEI-3, Intermediate Response Form; Battle, 2002) and the Social Skills Rating System (SSRS, Teacher Form Elementary Level; Gresham & Elliott, 1990).

The CMS is a comprehensive measure of learning and memory for children aged 5 to 16 years, which consists of a core battery of six subtests (Cohen, 1997). The Word Pairs subtest measures learning, immediate and delayed recall and recognition of verbal information. Participants are required to listen to and recall a list of 14 word pairs over three learning trials ('Verbal learning'), as well as perform

Table 1: Comparison of Demographics of Music Training (Intensive Strings) Program (MT) and Control Groups. (SD= Standard deviation) Figure 1.

	Music Training program (MT)	Standard music classes (Control)
Number of schools	5	4
Mean students per school testing group	14	10
Sample size Baseline test (F:M)	82 (41:41)	60 (31:29)
Sample size After 2 years test (F:M)	68 (37:31)	47 (25:22)
Mean age (at baseline)	8.62 (SD:0.61)	8.79 (SD: 0.68)
Previous formal instrumental training	27.8%	30.30%
Socioeconomic status units (school)	0.46 (SD 0.06)	0.48 (SD 0.09)
Distance from regional centre	39.4 km	42.9 km
Distance from local centre	8.4 km	7.9 km

an immediate recall ('Immediate memory'), delayed recall ('Delayed memory') and delayed recognition ('Verbal recognition') tests. The Digit Span Forward subtest ('Digit span') assesses attention and concentration by testing the ability to repeat random digit sequences of graduated length, up to 9 numbers (Cohen, 1997). The CMS is designed to be individually administered with oral responses, however, due to class testing arrangements, group administration and written response variations were used following the author's advice that it should still assess target constructs if appropriate testing conditions were used (Cohen, personal communication, 22/1/2005). Internal consistency coefficients for the subtests reported by Cohen (1997) range from 0.71 - 0.91 for the verbal and nonverbal subtests, 0.72 - 0.84 for the delayed recall tasks, and 0.75 - 0.79 for the delayed recognition tasks. The CMS also demonstrates good construct validity (between immediate and delayed recall measures and subtests within the same domain) and convergent validity, correlating strongly with other measures of memory and learning (Vaupel, 2001).

The BVRT (Sivan, 1992) was used to assess visual recall ('Immediate visual memory'), and perceptual – copying ability ('Visual performance'). The BVRT provides three alternative forms of the task (Form C, D and E) which may be administered by four different methods (A, B, C and D). Each form has ten designs, with each design containing up to three figures. Forms C and D were used in this study, however, only eight of the designs for each form were administered due to time constraints, and data indicating maintenance of psychometric properties with this shorter form (Sivan, 1992). The Form C designs were viewed by the participants for 10 seconds via an overhead projector and immediately reproduced from memory (Administration A). The Form D designs remained in the participant's view while being reproduced (Administration C). This provides a measure of visual perception, which enables differences in visual ability to be distinguished from differences in visual memory per se. Inter-scorer agreement for the BVRT has been found to be very high with correlation coefficients ranging from 0.90-0.98 for Administration A and 0.97 for Administration C. In addition, various correlational and factor analyses have identified that the abilities underlying performance on Administration A are short term memory and visual perception while Administration C reflects visuoconstructive abilities (Sivan, 1992).

Procedure

Due to constraints of a school-based program, the conditions were necessarily nested within schools. All students for whom parental/guardian permission had been obtained to participate in this study were tested at baseline. These students were tested again approximately one year (12-13 months after baseline), and two years (25-26 months after baseline) later. In the third year, a sub-set of the control sample (N=44) was tested again after approximately 1 year of either juggling or continued standard music classes.

The test battery (approximately 90 minutes' duration) was conducted in the following order: demographics, CMS verbal learning and immediate recall, short break, BVRT form C and D, CFSEI-3, short break, CMS delayed recall and delayed recognition, Digit Span Forward. Testing was conducted in a classroom, with tables organized in a way (including a barrier set between students) that prevented copying. Across the three years of testing, full data was obtained for 76.2% of the sample. All procedures for this study were approved by Monash University's Standing Committee on Ethics in Research.

The Music Training (Intensive Strings) program (MT):

Five schools received the classroom-based strings program for 2½-3 years as part of their school curriculum. The aim of the intervention/program was to increase the frequency of student exposure to music instruction by providing additional 1 hour, group string classes weekly, and to introduce a sequential and movementbased age-appropriate strings pedagogy (based on the teaching philosophies of string educators Paul Rolland and Sheila Neilson) into school-based music classes. The program incorporated improvisation and game play in an attempt to make the students' early string experience enjoyable and satisfying, and to encourage broader learning outcomes than basic acquisition of the skills needed to play an instrument. These additional string classes were over and above the normal curriculum, as each school also maintained their general music program (up to 1 hour per week). There was also opportunity for students to participate in private instrumental tuition and limited ensemble and vocal groups. As the program was introduced as part of the curriculum, whole class participation was required.

The string classes ranged in size from 10-24 students, with two teachers, one leader and one assistant per class. In general, these were mixed string groups consisting of violins, violas and cellos organised in an orchestral layout, although initially the cello students attended separate classes. Instruments were purchased and owned by the schools and allocated to each student rather than being distributed according to individual preference. A typical class included tuning, singing, rhythm training, solfège, basic music literacy, teacher demonstration and the development of listening and performance skills using simple beginner level nursery rhymes and folk tunes with up to four different parts. Over the duration of the program, parents and teachers reported limited compliance with instrumental practice at home. Despite some difficulty implementing an intensive music education program into this cluster of regional schools, the program did represent a considerable improvement on the usual curriculum and was highly unusual for an entire cluster of regional schools to adopt such a program (see Grimmett et al., 2009 for full evaluation of program implementation). In addition, students receiving the strings program were assessed sequentially on their ability to clap the beat, clap rhythms, differentiate between beat and rhythm, sing in tune, read simple rhythms, discriminate between high and low sounds at various intervals and echo and sight-sing simple melodic patterns. Students receiving the music training program showed significant improvement after the program, with achievement scores improving from baseline ($M=39.88$, $SD=15.46$) to post-program ($M=56.61$, $SD=15.38$), $t(62)=7.20$, $p<.05$.

The Control program:

Four schools continued to receive their usual music classes, which were often run by non-specialist music teachers and included some singing and rhythm activities, percussion instrument activities and (at one school) performing arts for 1 hour per week. To ensure some parity of the music education initiative in this regional cluster of schools, additional group music (e.g. percussion ensemble) and vocal classes were available to all schools. However, one control school was not exposed to any new music education and one school allocated to the MT condition received the main program only.

The Juggling program:

A juggling program was introduced to one control school for a duration period of one year. The juggling program was a structured and sequential sequence of weekly one hour classes instructed by experienced circus skills trainers. The juggling program introduced cascade scarves, spinning and rotating devil-sticks, 2 ball juggling, single ring and club activities, plate spinning, flipping, throwing catching and passing, diabolo-whirling, catching and tossing and poi patterns.

Results

The quasi-experimental design was mixed model, with the *Group* as the between groups factor, and *time* the within groups factor. Because the treatment was nested within schools, schools, *school* was entered as a nested factor.

Effect of the Intensive Strings Music Training program

The means and standard deviations for each CMS measure are shown for each condition following 12 ('After 1 year') and 26 months ('After 2 years') of the music or control programs are shown in Figure 1. Assumptions were tested (normality, Mauchly's test of sphericity, Box's M test of equality of covariance matrices) and were met in all cases except the following. The distribution of verbal recognition scores was found to be highly negatively skewed, with the majority of children appeared to be performing at or near ceiling level, and therefore these data were not analysed. Box's M was found to be significant for Delayed Verbal Recall and Digit Recall (Attention) data. In these cases, the probability values should be interpreted as being overly conservative as the variability was greater in the MT group which had the larger sample sizes (Tabachnik & Fidell, 2001).

Figure 1 reveals that across the 3 years, students in the MT group demonstrated a greater improvement than did the Control group on every measure except Verbal Delayed recall. Mixed model nested ANOVAs revealed significant test-time by group effects for verbal learning ($F(2,208)=8.18$, $p<.001$, $\eta_p^2=.073$), verbal immediate recall ($F(2,210)=3.82$, $p=.024$, $\eta_p^2=.035$) and visual perception ($F(2,212)=3.16$, $p=.045$, $\eta_p^2=.029$) scores. Post-hoc analyses (one-way ANOVAs) revealed that there was a significantly greater improvement in the MT group in the first year of the program for verbal learning scores ($F(1,133)=14.98$, $p<.001$, $\eta_p^2=.101$) and immediate verbal recall scores ($F(1,133)=4.75$, $p=.031$, $\eta_p^2=.034$). However, the control group experienced greater improvement in immediate recall in the second year than did the music group, ($F(1,105)=4.68$, $p=.033$, $\eta_p^2=.043$). While the control group experienced a decline in visual *perception* (but not visual memory) scores from the first to second year, scores were maintained in the music group, $F(1,106)=6.60$, $p=.012$, $\eta_p^2=.059$). Finally, while the interaction effect across three years approached significance, digit span scores improved significantly more in the Music Training group than in the control group from the second to third year, $F(1,100)=4.30$, $p=.041$, $\eta_p^2=.041$).

Effect of the Juggling program

Due to the considerably smaller sample sizes, different age at onset of the program and shorter duration of the juggling program prevent inclusion of these data into the main analyses. However, the descriptive data are illustrated in Figure 1. As this cohort were substantially older when the juggling program was introduced, the means were normalized using age-matched controls to enable visual comparison with the music program during its first year of implementation. These data reveal that and reveal that one year of a juggling program did not produce any of the substantial improvements observed after one year of the music program.

Discussion

The current study contributes to much needed longitudinal and experimental research into cognitive benefits of school-based music programs. The primary finding in this research was that one year of a strings-based instrumental program significantly enhanced students' learning and immediate recall of verbal information, while a similarly novel juggling program did not. This finding was present when the potentially confounding effects of age and school were controlled, and was surprisingly robust given the challenges inherent in implementing a school-based program into a cluster of regional primary schools. The effect, however, did not persist into the second year, nor was any effect of the program on delayed recall of verbal information observed. As anticipated, music instruction had no effect on recall of visual information, although surprisingly, the music program appeared to counter a decline in visual

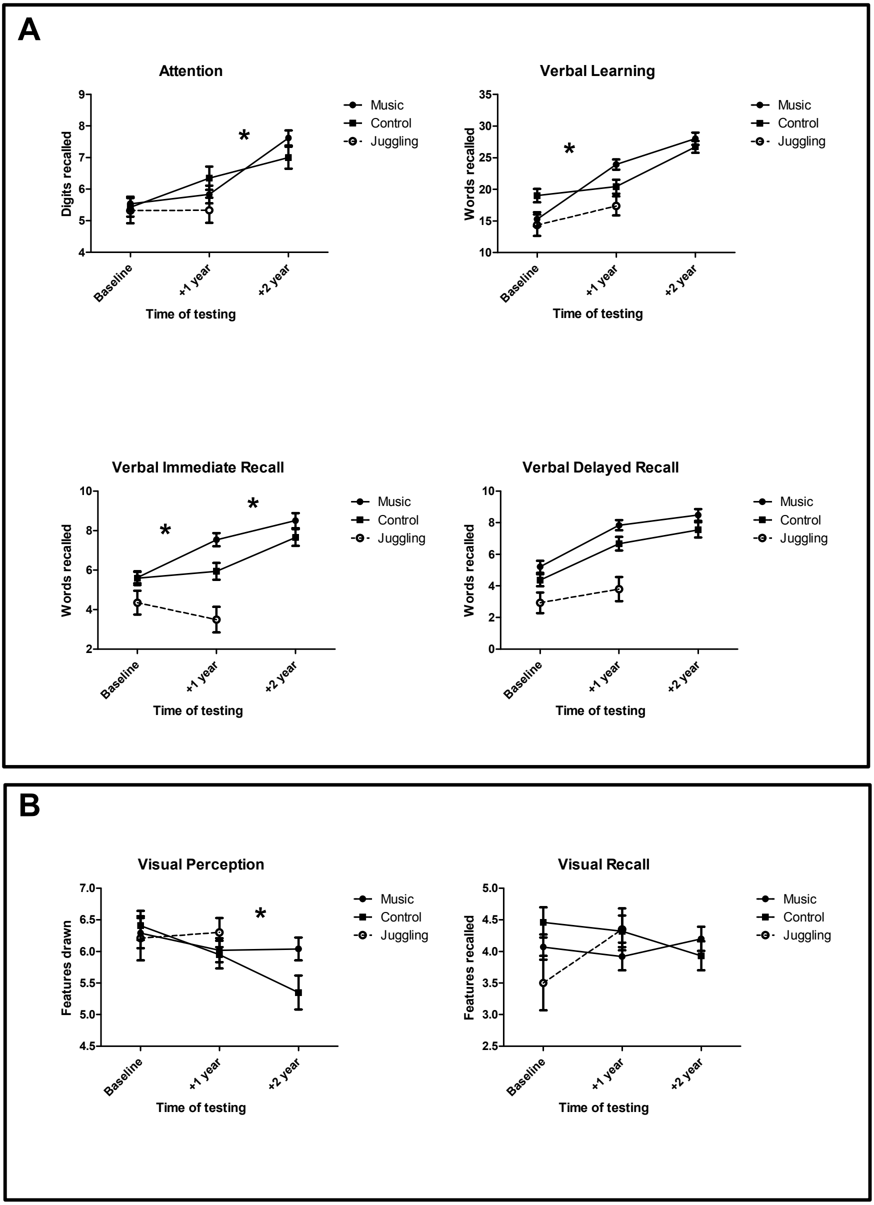

*Figure 1: Effects of Music Training (Intensive Strings) Program and Control programs after One or Two Years on (A) Verbal Memory and (B) Visual Performance measures. (Standardized Juggling Scores also illustrated.) * p<.05 for time by group interaction effect.*

perceptual ability experienced by controls in the second year. Taken together, these data indicated that the music skills trained in this program (including rhythm training, instrument tuning and basic music literacy) may have developed acquisition and short-term working memory capacity rather than long-term consolidation processes.

The finding that music training had a positive effect on acquisition and short-term recall of verbal information is consistent with previous correlational/quasi-experimental research. For instance, musically trained adults (Kilgour et al., 2000) and children (Ho et al., 2003) have been shown to demonstrate better verbal memory than untrained individuals. The current data extend these previous findings in that they are the first (to our knowledge) to demonstrate - within an experimental design - that an aspect of memory can be improved by implementing a *school-based* music instruction program. Moreover, that this benefit could be detected despite considerable variability in each school's adoption of the program, and difficulties maintaining adequate staffing across schools (see Grimmett et al., 2009), is notable. While the effect size (when the effects of age and school were controlled) was quite small, this is consistent with the effect size for music lessons in predicting to intelligence scores, which ranged from 5 to 7% (Schellenberg, 2006). The finding in the current study that music training also enhanced visual perceptual (but not visual recall) ability in its second year of implementation is intriguing. A similar trend in digit span (attention) scores in the second year raises the possibility that the music program trains the capacity to focus attention, which generalizes to an ability to pay closer attention to both visual and digit span stimuli.

The specific benefits observed in the current study are in contrast to the more generalized effects observed by others (Franklin et al., 2008; Ho et al., 2003). This may be a result of greater experimental control of pre-existing difference afforded by the quasi-random allocation of students to the experimental groups in this study, or it could be a result of reduced sensitivity due to group administration of the CMS subtest. Alternatively, the more limited effects may be due to the nature of the particular program implemented. The frequency of additional music classes consisted of an additional hour of classroom based instrumental training, and while encouraged, adherence to a rigorous practice regime at home was limited. The broader benefits to delayed recall previously reported in the literature may only occur with the more intensive training possible with private tuition. It is possible that the limited individual attention to formal techniques, intonation and posture, insufficient rehearsal time and excessive class time spent tuning, which are all inevitable with larger class sizes, prevent critical musicianship skills. For instance, refinement of auditory processing ability, focussed rehearsal and enhanced synaptic plasticity, which have each been speculated to be mediators of enhanced cognitive function (Schellenberg, 2001; Jacobson et al., 2003), may not be sufficiently developed in the classroom context. It should be noted that the music training group in the study by Ho et al. (2003) were at the outset considerably more advanced than those in the current study, with at least 3 years of music training prior to program discontinuation, as well as exposure to private instrumental tuition, band and orchestral sessions. In contrast, our sample was quite musically naive prior to introduction of this program, with less than a third having received any formal music training. It remains possible then that musical experience moderates the longevity of benefits produced by music training, and that more extensive effects may be observed with more advanced music classroom training. It is therefore notable that a robust effect following this class-based program was observed after only one year, and implies that benefits are not solely mediated by development of advanced musicianship skills.

The current study is one of the first to evaluate the cognitive effects of a long-term music program beyond one year. Ho et al. (2003) compared children who continued with music training with those who discontinued for one year. They found that the superiority observed in musically trained students was maintained once the training had been discontinued. However, these children were not followed longitudinally beyond one year. Consistent with these findings, the students in our study showed rapid improvement over the first year of implementation of the program. However, in our 2 year follow-up, the difference between the music and control students in verbal learning and immediate recall had ameliorated considerably, despite continuation of the program. While Ho and colleagues argue that music training produced stable and long-lasting effects on verbal memory, in our sample, the benefits were transient. This has significant implications for development of remedial interventions that could benefit from an enhancement of verbal memory skill in that this adjunct would need to be introduced in a timely fashion to confer benefits. For instance, literacy programs for that depend on learning of verbal information may, if offered at the appropriate time, be facilitated in the short-term by introduction of a concurrent instrumental music program.

Importantly, the improvement in verbal memory observed is unlikely to be associated with the novelty of introducing a performance-based program and associated new staff, or relief from the students' usual curriculum. Previous research has been criticized for not including sufficient conditions to control for this possibility (Schellenberg, 2004). This salient confound was investigated in the current study by measuring verbal memory in a sub-set of the sample after one year of an alternative performance-based program. Despite the novelty and engaging nature of the juggling program, and the similar requirements for practice, skill development and performance, juggling students demonstrated no significant improvements in verbal recall relative to controls. While this sub-sample was limited in size, the absence of any trends suggest that the benefits observed after one year of the music program were not simply due to novelty, and are due to components of music training that are not shared by at least one other engaging arts based activity.

The mechanisms underlying the improvement in verbal recall observed in the current study cannot be determined from this data set. There are, however, various interpretations of non-musical benefits of music instruction. At a neurophysiological level, it has been suggested that music training enhances auditory temporal processing abilities (Jacobsen et al., 2003) and neuroplasticity in auditory regions (Schlaug et al., 1995; Munte et al., 2002) which may also advantage non-musical cognitive functions. At a psychological level, there are multiple functions that could benefit from music training, including enhanced self-esteem, attention, and social skills. Research exploring the impact of class-based instrumental programs on psychosocial competence would therefore be of interest to extend positive findings with private tuition (e.g., Costa-Giomi, 2004). Regardless of the mechanism, taken together with previous research showing that music training can enhance literacy skills in 8 year olds (e.g., Moreno, 2009) and neuronal plasticity in auditory cortex (Lappe, Herholz, Trainor & Pantev, 2008), the current findings provide strong evidence that music training may be an effective means of facilitating literacy training in primary school aged children.

In conclusion, this study demonstrated that music training may have significant benefits for children in terms of enhancing non-musical cognitive functions, such as verbal memory. While the observed benefits were modest, they did appear to be attributable to the instrumental program as they were not replicated with the similarly engaging and performance-based juggling program. Such findings support calls for enhanced access to music education for all students, and demonstrate that – while perhaps not as effective as private tuition – class-based instrumental training may still yield measurable benefits for academically relevant cognitive functions. Improved recall of verbal information for instance could have implications for children's literacy and comprehension. Classroom-based instrumental programs may therefore be a useful supplement to other interventions for reading or learning disabled children, particularly during the first year of the program.

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