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Long-Term Positive Associations Between Music Lessons and IQ

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In Study 1 ($N = 147$), duration of music lessons was correlated positively with IQ and with academic ability among 6- to 11-year-olds, even when potential confounding variables (i.e., family income, parents' education, involvement in nonmusical activities) were held constant. In Study 2 ($N = 150$), similar but weaker associations between playing music in childhood and intellectual functioning were evident among undergraduates. In both studies, there was no evidence that musical involvement had stronger associations with some aspects of cognitive ability (e.g., mathematical, spatial–temporal, verbal) than with others. These results indicate that formal exposure to music in childhood is associated positively with IQ and with academic performance and that such associations are small but general and long lasting.

Keywords: cognitive development, intelligence, intellectual development, musical training, positive transfer

Since the publication of an article in *Nature* more than 10 years ago (Rauscher, Shaw, & Ky, 1993), the idea that music makes you smarter has become embedded in the public consciousness with much attention from the popular media and governments. The proposed connection between music and intelligence represents a classic case of a simple solution (exposure to music) to a complex problem (enhancing intelligence). But is there really an association between music and intelligence? Are observed associations limited to specific subsets of intellectual ability (mathematical, verbal, etc.)? Are the associations large enough to have practical significance? If we observe an association between music lessons and intelligence, how can we explain it? These questions motivated the present investigation, which examined the possibility of associations between music lessons and intellectual functioning.

The proposed link between music and intelligence stems from two separate lines of research (Schellenberg, 2003, 2005, 2006). One focuses on passive listening to music, the other on formal music lessons. The original report (Rauscher et al., 1993) indicated that spatial performance was enhanced for approximately 10 minutes after listening to music composed by Mozart. We now know that such enhancement is a consequence of the listener's arousal level and mood (Husain, Thompson, & Schellenberg, 2002; Schellenberg, Nakata, Hunter, & Tamoto, in press; Thompson, Schellenberg, & Husain, 2001). Listening to music, particularly to music one enjoys, is more arousing than sitting in silence (the typical control condition) and more likely to evoke a positive mood. For adults, listening to a recording by Mozart or Schubert can lead to improved performance on subtests (spatial or otherwise) from standardized IQ tests (Nantais & Schellenberg, 1999; Schellenberg et al., in press; Thompson et al., 2001). For 10- and 11-year-olds, listening to pop music improves cognitive performance (Schellenberg & Hallam, 2005). For 5-year-olds, listening to children's songs improves creativity (Schellenberg et al., in press). These results are consistent with well-established effects of music on arousal and mood (Gabrielsson, 2001; Krumhansl, 1997; Peretz, 2001; Schmidt & Trainor, 2001; Sloboda & Juslin, 2001; Thayer & Levenson, 1983), and with effects of arousal and mood on a variety of outcome measures (Berlyne, 1967; Isen & Daubman, 1984; Isen, Niedenthal, & Cantor, 1992; Khan & Isen, 1993; O'Hanlon, 1981; Sarason, 1980; Yoon, May, & Hasher, 2000).

The issue of associations between music lessons and intellectual development is a different story and the focus of the present report. Musical training leads to improved performance on a wide variety of tasks involving music perception and cognition (for reviews, see Dowling & Harwood, 1986; Krumhansl, 1990; Smith, 1997), which comes as no surprise. Studying and playing music helps one to become a more sophisticated music listener. Music lessons also help listeners to perceive pitch patterns (i.e., prosody) in speech (Magne, Schön, & Besson, 2006; Schön, Magne, & Besson, 2004) and to decode the emotions conveyed by such patterns (Thompson, Schellenberg, & Husain, 2003, 2004). More provocative questions include whether music lessons are associated with nonmusical skills, and whether such associations are both systematic (i.e., evident across individuals) and music specific (i.e., different from associations with other out-of-school activities).

Some researchers propose that training in music is associated with specific subareas of intellectual abilities, such as mathematical, spatial–temporal, or verbal abilities. In fact, the belief that musical and mathematical abilities are intimately linked is relatively widespread, yet a review of the literature reveals that this association is based largely on anecdotal rather than empirical evidence, although some scholars (e.g., Rauscher, 2002; Shaw, 2000) subscribe to it as well. A recent meta-analysis (Vaughn, 2000) comprising only eight correlational and five experimental

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studies concluded that taking music lessons had a small positive association with mathematical abilities (see also Cheek & Smith, 1999). There is also modest empirical support for associations between music lessons and spatial–temporal abilities (Hetland, 2000; Rauscher, 1999, 2002; Rauscher et al., 1993), and between musical training and reading abilities (Butzlaff, 2000; Hurwitz, Wolff, Bortnick, & Kokas, 1975) or subcomponents of literacy such as vocabulary (Orsmond & Miller, 1999) and verbal memory (Brandler & Rammsayer, 2003; Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003; Jakobson, Cuddy, & Kilgour, 2003; Kilgour, Jakobson, & Cuddy, 2000). Jakobson et al. (2003) propose that the association between musical training and verbal memory is subserved by an underlying mechanism for processing temporal order in the auditory domain, which is fine-tuned by studying music.

Other correlational findings reveal that music lessons are predictive of enhanced spatial (as opposed to spatial–temporal) skills (Bilhartz, Bruhn, & Olson, 2000; Gromko & Poorman, 1998; Hetland, 2000; Hurwitz et al., 1975), selective attention (Hurwitz et al., 1975; Orsmond & Miller, 1999), visual perception and imagery (Brochard, Dufour, & Després, 2004), and visual–motor skills (Orsmond & Miller, 1999). If these associations are causal in origin, then, considered as a whole, their diversity suggests that either (1) taking music lessons affects a broad range of cognitive abilities rather than a specific subset or (2) children with high IQs (who perform well in a variety of test settings) are more likely than other children to take music lessons. Third factors could also account for part or all of the observed associations. For example, children who take music lessons tend to have well-educated and financially successful parents (Sergeant & Thatcher, 1974). IQ is known to have a substantial genetic component (Petrill et al., 2004; Plomin, Fulker, Corely, & DeFries, 1997) and to be associated positively with educational achievement (Ceci & Williams, 1997; Neisser et al., 1996; Wechsler, 1991) and with career status (Gottfredson, 1997, 2002; Schmidt & Hunter, 1998). Previous correlational research has failed to account for these potential confounding variables, either through statistical means or by recruiting groups that are equivalent on these dimensions.

Previous experimental studies have examined whether music lessons cause intellectual benefits. In one instance, 4-year-old children who received individual 10-min piano lessons once or twice a week for 6 to 8 months performed better on a test of spatial skills than children assigned to comparison conditions (Rauscher et al., 1997). In another instance, young children assigned to keyboard lessons demonstrated enhanced abilities on tests of spatial–temporal abilities but not on a memory test (Rauscher, 2002). In another study (Gardiner, Fox, Knowles, & Jeffrey, 1996), entire classes of first-grade children were assigned to "test" arts programs, which included specialized classes in music and visual arts. After 6 months, these children had larger improvements on standardized tests of reading and arithmetic compared to children receiving the standard curriculum.

In the most comprehensive experimental study to date (Schellenberg, 2004), 144 families with 6-year-old children were recruited by advertising for free arts lessons. The children were assigned randomly to one of four conditions. In two conditions, they received music lessons taught in small groups while they were in first grade, either standard conservatory keyboard lessons or vocal lessons taught with the Kodály method (Choksy, 1999). One of two control groups received drama lessons for the same length of time. The other control group received no lessons (they took keyboard lessons while they were in second grade). Each child was administered the entire Wechsler Intelligence Scale for Children—Third Edition (WISC–III; Wechsler, 1991) before entering first grade (and before beginning the lessons) and again in the summer between first and second grade (after the lessons). All of the groups exhibited a significant increase in full-scale IQ (FSIQ) from prelessons to postlessons, which is consistent with the increases in FSIQ that accompany attendance at school (Ceci, 1991; Ceci & Williams, 1997). The two music groups did not differ in this regard, nor did the two control groups, but the music groups had significantly larger increases than the control groups. The effect was relatively small (i.e., increase of 7.0 points in FSIQ for the music groups, 4.3 points for the control groups), but it generalized across the WISC–III index scores, the individual subtests, and a standardized test of academic achievement. In other words, the results pointed to a general effect of music lessons on intelligence, contrary to each of the "specific-link" hypotheses. An incidental finding revealed that adaptive social behavior was enhanced by the drama lessons.

Although experiments allow for inferences of causation, Schellenberg's (2004) results do not tell us how long the effect of music lessons on IQ will last or whether it would increase with additional training. In a longer experiment that spanned 3 years, 9-year-olds were assigned randomly to piano lessons or no lessons; the two groups did not differ in IQ at the end of the study (Costa-Giomi, 1999), and there was no effect on academic achievement (Costa-Giomi, 2004). Most notably, attrition in the piano group was over 35%. In summary, longer-term experimental studies are likely to produce results that are difficult to interpret because of problems with attrition and internal validity.

In the present investigation, two correlational studies were used to examine associations between music lessons and intellectual functioning. The studies are unique for at least four reasons. First, the principal predictor variable was duration of musical involvement, which allowed for tests of whether longer involvement was associated with greater increases in cognitive ability. In both samples, total duration of musical involvement varied widely, which made it ideal for use in correlational analyses. Second, potential confounding variables such as family income and parents' education were measured and held constant by statistical means. Third, the criterion variables included entire standardized IQ tests, which provide the most direct tests of whether music lessons are associated with intelligence. IQ tests also have separate subtests and index scores that allow for evaluation of competing hypotheses of general (Schellenberg, 2005, in press) or specific (e.g., Butzlaff, 2000; Chan et al., 1998; Hetland, 2000; Jakobson et al., 2003; Rauscher, 2002; Shaw, 2000) links between music and intellectual abilities. Fourth, measures of academic achievement and social adjustment were included to examine whether observed associations between musical training and intellectual ability extend to applied measures but not to nonintellectual domains.

Study 1

The principle goal of the first study was to test the prediction that duration of music lessons in childhood is associated positively with IQ. The participants were 6- to 11-year-old children who varied in amount of musical training. Each child was administered the entire WISC–III (Wechsler, 1991). We also tested whether associations with music lessons would extend to more applied measures of intellectual functioning (i.e., grades in school, standardized tests of academic achievement) but *not* to measures of social adjustment.

If music lessons are associated with general intellectual functioning, significant correlations should be evident across the various intelligence and academic measures, including the most general measures (e.g., FSIQ, average grade in school). By contrast, if taking music lessons were associated with specific subcomponents of cognitive functioning, one would expect to see associations with some measures but not with others. Moreover, to conclude unequivocally that music lessons have an association with some aspects of intelligence but not with others, observed specific associations should remain evident after accounting for contributions from general intelligence.

Method

Participants. The sample comprised 147 6- to 11-year-olds (M = 9 years 1 month; SD = 1 year 6 months, 72 boys and 75 girls) recruited from a middle-class suburb of Toronto, a large Canadian city. Most of the children (96%) were born in Canada, and 94% spoke English as their first language. We specifically targeted children with music lessons so that 56% of the sample (82 children) had a history of private lessons (n = 53), group lessons (n = 10), or both private and group lessons (n = 19). On average, the 82 children with music lessons had 22.9 months of private lessons (SD = 19.1) and 5.1 months of out-of-school group lessons (SD = 10.7).

The vast majority (91%) of the entire sample had participated in organized nonmusical out-of-school activities for an average of 56.0 months (SD = 47.3 months). Approximately one third (35%) had participated in nonmusical arts-related activities for an average of 27.8 months (SD = 26.2 months), 85% had participated in organized sports (M = 36.5 months, SD = 31.6 months), and 38% had participated in other nonmusical out-of-school activities (M = 27.3 months, SD = 22.4 months).

All but two of the participants came from families who had participated previously in cognitive-developmental research on campus and expressed a willingness to return. The families were contacted by telephone and asked whether they would participate in a study on music lessons and cognitive abilities. Although the testing session involved a longer time commitment than typical on-campus studies, families were generally interested in the topic and their agreement about whether to participate was not noticeably different from other recruitment efforts from the same laboratory. Rather, such agreement depended almost solely on the families' schedules at the time they were contacted. Each child was given a $15 gift certificate ($1 CAD ≅ $0.85 USD) at the end of the testing session as a means of thanking the families for their time. The gift certificate was not used as a lure to participate or to dissuade any child from discontinuing participation.

Because the sample was comprised solely of volunteers, it was undoubtedly more homogeneous in some respects than a sample from the general population. Nevertheless, the local community is very diverse culturally and economically, and the sample reflected this diversity. For example, a sizable minority of the children (41%) had at least one parent who was born outside of Canada. The parents' linguistic background was similarly heterogeneous with 56%, 24%, and 20% of children having two, one, or no parents, respectively, who spoke English as their native tongue. Parental first languages other than English were primarily European (19%) or Chinese (7%). Parents' education also varied widely, with 16% of fathers and 29% of mothers having a high school education or less, and 19% of fathers and 14% of mothers having a postgraduate degree or some postgraduate training. The annual income of most families (71%) was between $50,000 and $125,000, but 12% of families had incomes of $50,000 or less, and 17% had incomes in excess of $125,000. All but four of the children were attending public school.

Measures. Predictor variables were measured with a questionnaire. Parents were asked to provide details about their child's history of private or group music lessons taken outside of school (i.e., months of involvement), which were rechecked and confirmed verbally by an assistant. The questionnaire also contained items about family income, linguistic background, country of birth, parents' education, and the child's involvement in nonmusical out-of-school activities. For statistical purposes, mothers' and fathers' education were recoded as integers that ranged from 1 (*some high school*) to 8 (*postgraduate degree*), so that a composite variable (i.e., *Parents' Education*, the average of the two scores) could be used in analyses.[1] *Family Income*, originally measured in increments of $25,000 per year, was recoded similarly, such that it ranged from 1 (< *$25,000*) to 9 (> *$200,000*). Information about nonmusical out-of-school activities was gathered separately for arts-related activities (e.g., drama, ballet), sports, and other organized activities (e.g., chess, computers). As with music lessons, each activity was measured in months of involvement. An aggregate variable (*Nonmusical Activities*) was calculated by summing the three scores.

Criterion variables consisted of measures of intelligence, academic ability, and social adjustment. The WISC–III is a test of childhood intelligence used widely in North America, with well-established reliability and validity (Wechsler, 1991). Raw scores on each of 12 subtests are converted into standardized scores (M = 10, SD = 3), which indicate the child's performance relative to other children of the same age (calibrated in 3-month intervals). The subtests are combined into four index scores: Verbal Comprehension (subtests: Information, Similarities, Vocabulary, and Comprehension), Perceptual Organization (subtests: Picture Completion, Picture Arrangement, Block Design, and Object Assembly), Freedom from Distractibility (subtests: Arithmetic and Digit Span), and Processing Speed (subtests: Coding and Symbol Search). FSIQ is formed from 10 of 12 subtests (all but Symbol Search and Digit Span). FSIQ and the index scores (M = 100, SD = 15) are derived from the standardized subtest scores such that effects of age are held constant. Canadian norms (used here) are slightly higher (4–5 points) than U.S. norms. For example, an FSIQ of 109 in Canada translates to an FSIQ of 113 in the United States.

Measures of academic achievement included the Kaufman Test of Educational Achievement—Brief Form (K-TEA; Kaufman & Kaufman, 1985), as well as school grades. The K-TEA is a standardized test of academic achievement from the United States that provides a composite score as well as scores on three subtests (Mathematics, Spelling, and Reading). As with the WISC–III, the composite and subtest scores have a mean of 100 and a standard deviation of 15, normed according to age (in 3-month intervals). The K-TEA has good reliability and validity (Kaufman & Kaufman, 1985).

Parents of 125 children (85% of the sample) provided photocopies of school report cards, which are identical across all publicly funded schools in Ontario and thus comparable. Comparisons between children from families who did or did not provide report cards confirmed that the two groups did not differ in duration of music lessons or in FSIQ ($ps > .6$). Report cards contained three grades ranging from A+ to D– in Language Arts (Reading, Writing, Oral and Visual Communication), five grades in Mathematics (Number Sense and Numeration, Measurement, Geometry and Spatial Sense, Patterning and Algebra, Data Management and Probability), three grades in the Arts (Music, Visual Arts, Drama and Dance), as well as separate grades in Science and Technology, Social Studies, and Health and Physical Education. Some age groups did not receive instruction and grades in all areas. For statistical analysis, letter grades were converted to integers (A+ = 12, A = 11, A– = 10, etc.). A composite

[1] Mothers' and fathers' education were highly correlated in Study 1 (r = .62, $p < .001$) and in Study 2 (r = .67, $p < .001$). In Study 1, both mothers' and fathers' education were correlated positively with FSIQ (rs = .32 and .40, respectively; $ps < .001$). In Study 2, neither mothers' nor fathers' education was correlated with FSIQ.

Table 1
Descriptive Statistics for Standardized Criterion Variables in Study 1 and Study 2

Study 1			Study 2		
Criterion variable	*M*	*SD*	Criterion variable	*M*	*SD*
FSIQ	110.6*	12.4	FSIQ	104.9*	11.5
Verbal Comprehension	110.1*	12.6	Verbal Comprehension	105.6*	12.9
Perceptual Organization	107.9*	14.1	Perceptual Organization	103.4*	11.3
Freedom from Distractibility	108.5*	13.8	Working Memory	106.5*	13.1
Processing Speed	111.1*	12.7	Processing Speed	111.4*	14.3
K-TEA	110.8*	15.1			
BSI	46.8**	9.8			
Adaptive Skills	54.0*	10.4			

Note. Study 1: children, $N = 147$. Study 2: undergraduates, $N = 150$. Canadian norms (slightly higher than U.S. norms) were used for the WISC–III and WAIS–III.
* significantly higher than published norm ($p < .001$). ** significantly lower than published norm ($p < .001$).

school average was the average of each child's grades. Report cards also contained grades on a four-point scale (*Excellent*, *Good*, *Satisfactory*, or *Needs Improvement*) in nine areas that measured learning skills (Independent Work, Initiative, Homework Completion, Use of Information, Cooperation with Others, Conflict Resolution, Class Participation, Problem Solving, and Goal Setting to Improve Work). These grades were converted to a numerical scale (e.g., *Excellent* = 4, *Needs Improvement* = 1) and averaged to yield a composite measure of Learning Skills. Analyses were limited to the two composite measures, as well as to averages calculated separately for language arts and mathematics.

Social adjustment was measured with the Parent Rating Scale of the Behavioral Assessment System for Children (BASC; Reynolds & Kamphaus, 1992). The BASC requires parents to complete a paper-and-pencil questionnaire that contains 138 items describing their child's behavior (e.g., listens to directions, threatens to hurt others). For each item, a parent selects one of four responses (*Never*, *Sometimes*, *Often*, *Almost Always*). Six maladaptive subtests (Hyperactivity, Aggression, Anxiety, Depression, Atypicality, and Attention Problems) form the Behavioral Symptoms Index (BSI). The BASC also has three adaptive subtests (Adaptability, Social Skills, and Leadership) that are combined to form an Adaptive Skills composite score. Raw scores are converted to *T* scores ($M = 50$, $SD = 10$), which indicate the child's social skills relative to the BASC standardization sample. Norms are provided separately for 6- and 7-year-olds and for 8- to 11-year-olds. The BASC has good reliability and validity (Reynolds & Kamphaus, 1992). Analyses were limited to the BSI (maladaptive) and the Adaptive Skills composite scores.

Procedure. Children were tested individually in a quiet room by a female assistant trained in administering the WISC–III, the K-TEA, and the BASC. The WISC–III was administered before the K-TEA. Each child took a short break halfway through the 12 subtests of the WISC–III and another break between the WISC–III and the K-TEA. Some children were given additional breaks as required. The typical testing procedure took between 2 and 2.5 hours. A parent completed the BASC and the background-information questionnaire while the child was being tested.

Results and Discussion

Preliminary analyses. Means and standard deviations for the standardized criterion measures are reported in Table 1. Average scores on the WISC–III (FSIQ and index scores) and the K-TEA were higher than published norms, which might be expected for a sample of children from suburban, middle-class families. Standard deviations tended to be slightly smaller than published norms, which indicates that variability in the present sample was slightly less than it is in the general population. Scores on the BASC were below average on the maladaptive BSI but above average on the Adaptive Skills measure. The average grade in school subjects was almost a B+ (12-point scale: $M = 8.9$, $SD = 1.3$), and the average learning-skills grade was *Good* (4-point scale: $M = 3.2$, $SD = 0.5$).

Principal components analysis of the WISC–III subtests (standard scores) revealed that a one-factor solution accounted for 33% of the variance in the 12 subtests. Each of the subtests loaded positively on the principal component (highest: Similarities, $r = .74$; lowest: Coding: $r = .25$). Factor scores on this IQ Principal Component (IQ-PC) were used in subsequent analyses as a measure of general intellectual ability, in addition to FSIQ.

Associations among predictor variables are provided in Table 2 (upper matrix). *Music lessons* represented total months of out-of-school private and group instruction in music. Significant correlations confirmed the need to account for potential confounding variables when examining associations that involve music lessons. Specifically, music lessons were correlated positively with nonmusical activities, parents' education, and age. Although family income was associated with parents' education, it was not significantly associated with music lessons. This null result may be attributed to cultural differences in the local community, both in income and in the relative emphasis placed on musical training.[2] It is interesting that gender was not associated with music lessons, but it was associated with nonmusical activities, with girls ($M = 62.6$) surpassing boys ($M = 38.6$) in months of involvement.

Associations among criterion measures are provided in Table 2 (lower matrix). As one would expect, significant correlations were observed among the IQ measures (FSIQ, IQ-PC, and index scores), among the measures of academic ability (K-TEA scores, school average, and Learning Skills), and between academic ability and the IQ measures. Children with higher WISC–III scores and academic abilities also tended to have higher scores on the Adaptive Skills composite score but somewhat lower scores on the maladaptive BSI (i.e., significant for school average and Learning Skills).

Principal analyses. Simple and partial correlations between the main predictor and criterion variables are provided in Table 3.

[2] Annual family income had a small positive association with number of Canadian-born parents ($r = .18$, $p < .05$), but not with parents' first language.

Table 2
Correlations Among Predictor Variables (Upper) and Criterion Variables (Lower) in Study 1

Predictor variables	1	2	3	4	5	6
1. Music lessons	—	.26†	.09	.35†	−.12	.30†
2. Nonmusical activities		—	.18**	.18**	−.25†	.21**
3. Family income			—	.26†	−.07	.11
4. Parents' education				—	−.04	.19**
5. Gender					—	−.04
6. Age						—

Criterion variables	1	2	3	4	5	6	7	8	9	10	11
1. FSIQ	—	.98†	.83†	.82†	.57†	.40†	.56†	.52†	.40†	−.13	.25†
2. IQ-PC		—	.85†	.79†	.62†	.42†	.60†	.54†	.41†	−.11	.25†
3. Verbal Comprehension			—	.45†	.38†	.23†	.52†	.43†	.35†	−.11	.25†
4. Perceptual Organization				—	.39†	.26†	.32†	.33†	.24†	−.05	.16*
5. Freedom From Distractibility					—	.29†	.60†	.42†	.29†	−.09	.13
6. Processing Speed						—	.29†	.37†	.30†	−.13	.14*
7. K-TEA							—	.57†	.48†	−.13	.13
8. School average								—	.73†	−.20**	.24†
9. Learning Skills									—	−.23**	.23†
10. BSI										—	−.56†
11. Adaptive Skills											—

Note. Music lessons and nonmusical activities are measured in months. Gender is dummy-coded (boys = 1, girls = 0). WISC–III scores are calculated with Canadian norms.
* $p < .1$. ** $p < .05$. † $p < .01$.

Music lessons were correlated positively with each measure of intelligence or academic ability but not with either social-adjustment measure. Analyses of effect sizes (i.e., percentage of variance explained: $r^2 \times 100$) revealed that individual differences in duration of music lessons accounted for 12% of the variance in FSIQ, 13% of the variance in IQ-PC, 13% of the variance in K-TEA composite scores, and 12% of the variance in school average. Because of overlap with the other predictor variables, the partial associations were smaller but still significant (with exception—the verbal comprehension and Freedom from Distractibility indexes, $ps < .1$) after family income, parents' education, months of nonmusical activities, and age were held constant. To illustrate, music lessons accounted for 6%, 7%, 5%, and 6% of the unexplained variance (i.e., $pr^2 \times 100$) in FSIQ, IQ-PC, K-TEA scores, and school average, respectively. In other words, associations between music lessons and intellectual abilities could not be attributed solely to contributions from confounding variables—at least not to those measured here.

To examine further the issue of specific versus general associations between music lessons and intellectual functioning, each of the 12 WISC–III subtests was regressed separately on duration of music lessons. The correlations were small but statistically significant for 11 of the 12 subtests (highest: Comprehension, $r = .25$, lowest: Symbol Search, $r = .17$, $p\text{s} < .05$). The one exception was

Table 3
Simple Correlations (and Partial Correlations in Parentheses) Between Predictor and Criterion Variables in Study 1

	Predictor variable			
Criterion variable	Music lessons	Nonmusical activities	Family income	Parents' education
FSIQ	.35† (.25†)	.11 (.02)	.23† (.15*)	.40† (.27†)
IQ-PC	.36† (.26†)	.12 (.01)	.26† (.18**)	.40† (.26†)
Verbal Comprehension	.28† (.17**)	.12 (.05)	.24† (.16*)	.34† (.20**)
Perceptual Organization	.24† (.18**)	.02 (−.06)	.14* (.07)	.31† (.24†)
Freedom from Distractibility	.27† (.15*)	.16* (.06)	.19** (.12)	.29† (.19**)
Processing Speed	.22† (.26†)	.06 (−.02)	.22** (.22**)	.09 (−.03)
K-TEA	.37† (.23†)	.13 (−.00)	.23† (.15*)	.40† (.26†)
School average	.34† (.25**)	.16* (.07)	.22** (.16)	.40† (.30†)
Learning Skills	.26† (.22**)	.10 (.08)	.10 (.03)	.36† (.30†)
BSI	−.02 (.05)	−.06 (−.01)	.00 (.06)	−.21** (−.24†)
Adaptive Skills	.02 (−.12)	.11 (−.03)	.09 (.02)	.22† (.22†)

Note. Partial correlations were calculated with the other predictors (as well as age) held constant. WISC–III scores are based on Canadian norms.
* $p < .1$. ** $p < .05$. † $p < .01$.

Object Assembly ($r = .12$), a subtest considered to measure spatial–temporal abilities (Rauscher et al., 1997). When the associations were retested while holding constant general intellectual ability (i.e., IQ-PC), the partial correlations with music lessons proved to be nonsignificant for each of the 12 subtests, as they were for each of the four index scores.

Separate examination of the three K-TEA subtests revealed that music lessons were a significant predictor in each case and that the observed associations were similar in magnitude (rs = .34, .31, and .31, respectively; ps $< .001$, for Mathematics, Reading, and Spelling). Separate examination of school grades in Language Arts and Mathematics also revealed significant associations with music lessons in both cases (rs = .23 and .25, respectively; ps $< .05$). As with the intellectual measures, these widespread associations between music lessons and the academic measures provide evidence that is inconsistent with each of the specific-link hypotheses. It is interesting that, after holding constant general intelligence (IQ-PC), partial associations with music lessons remained significant for the K-TEA composite score, the Mathematics and Spelling subtests, and school average (prs = .20, .19, .19, and .19, respectively; ps $< .05$). In other words, school performance was predicted by duration of music lessons, and these associations were above and beyond contributions from general intelligence.

Turning now to the other predictor variables (see Table 3), associations involving parents' education extended across the intellectual measures except for the Processing Speed index. Unlike music lessons, parents' education was also correlated with adaptive and maladaptive social adjustment. Family income had a simple association with most of the intelligence and academic measures (all but Perceptual Organization and Learning Skills), but the partial correlation was significant in only two instances (IQ-PC and Processing Speed). Involvement in nonmusical out-of-school activities was not correlated significantly with any of the criterion measures.[3]

Summary. Duration of music lessons had small, positive associations with measures of intelligence. These associations were general and broad rather than specific to a subset of abilities, they extended to grades in school but not to measures of social functioning, and they could not be attributed to potential confounding variables such as family income, parents' education, or involvement in nonmusical out-of-school activities. Music lessons were also associated positively with academic performance even after individual differences in general intelligence were held constant. By contrast, nonmusical out-of-school activities were not associated with intelligence or with academic performance.

Study 2

Study 2 explored the possibility of more long-term associations between playing music and intellectual abilities, specifically whether these associations might persist after music lessons ended. Freshmen were administered an IQ test and asked about their grades in high school, their history of music lessons, and their family background (i.e., family income, parents' education). Most students who had taken music lessons had stopped several years previously.

Associations between playing music and intellectual functioning were expected to be smaller and less consistent than those reported in Study 1, simply because a greater length of time had passed, allowing other determinants of intellectual abilities to play a greater role. For example, the influence of genetic factors on IQ increases throughout childhood and the teenage years (Plomin et al., 1997). As in the first study, additional goals were to investigate whether taking music lessons would have general or specific associations with intellectual abilities, and to determine whether any observed associations would remain evident after accounting for potential confounding variables.

Method

Participants. The participants were undergraduates at a suburban university campus in Toronto, a large metropolitan area in Canada, and were recruited to participate in a study on music lessons and cognitive abilities. The testing session was typically 2 hours in duration. Most (92%) of the students were registered in an introductory psychology course and received partial course credit for participating. If the testing time exceeded 2.5 hours, these students received an additional \$10. Other students received \$20. Course credit and remuneration are regulated on campus by the psychology department so that they do not differ from study to study (i.e., 1% credit or \$10 per hour of participation). In other words, participation in the present study had no special benefits for the students.

Participants ranged in age from 16 to 25 years ($M = 19.6$ years, $SD = 1.3$ years) and 72% were female. Although the sample reflected the age and gender distribution of the introductory psychology class, students with music lessons were oversampled. Three quarters ($n = 112$) had taken group music lessons for an average of 3.7 years ($SD = 3.0$), but all of these were taught in school so the focus was limited to out-of-school private lessons. More than half (56%, $n = 84$) had taken private lessons for an average of 7.8 years ($SD = 5.9$ years), which were accompanied by an average of 9.4 years ($SD = 6.5$ years) of playing music regularly. On average, the lessons were discontinued 4.0 years previously ($SD = 3.6$ years), with regular playing ending 3.3 years before participating in the study ($SD = 3.8$ years). A small minority ($n = 14$) was currently taking lessons or had quit less than a year previously.

As in Study 1, the present sample was diverse ethnically and economically, reflecting the makeup of the local community. Responses to demographic questions indicated that 36% were born outside of Canada, and 40% had a first language other than English. Native languages other than English were primarily European (19%), Chinese (10%), or other East Asian languages (e.g., Korean or Vietnamese; 5%). Only 28% of students' parents were born in Canada, and a minority of mothers and fathers (39% and 38%, respectively) spoke English as their first language. More than one quarter of students' mothers (30%) and fathers (26%) had only a high school education or less, but 15% of mothers and 31% of fathers had a postgraduate degree or some postgraduate training. Most of the students (64%) were in families with annual incomes between \$50,000 and \$125,000, with 20% coming from families with incomes under \$50,000 and 16% from families with incomes exceeding \$125,000.

Measures. The predictor variables were quantified based on responses to a questionnaire. Students were asked about their history of music lessons. For each instrument they studied (including voice), they were also asked to indicate how long they had played it on a regular basis (i.e., number of years), including when they started and stopped taking lessons and when they started and stopped playing regularly. After responding in writing to each of these items, an assistant went over each response with each participant to verify accurate self-reporting and to make sure that the

[3] Besides the aggregate measure, months of nonmusical activities were calculated separately for sports, arts, and other activities. The arts, other, and aggregate measures were not correlated with FSIQ (ps $> .19$). Months of involvement in sports had a small but significant correlation with FSIQ ($r = .18$, $p < .05$), but this association was not significant when music lessons, family income, parents' education, and age were held constant ($p > .2$).

numbers added up (e.g., present year – years since last lessons = year lessons were discontinued). Compared to music lessons, regular playing was assumed to be a better reflection of students' actual commitment to musical training and to be a better indicator of musical interest and enjoyment. Thus, the predictor variable used in the statistical analyses was *years of playing music regularly* that accompanied private lessons (i.e., years of lessons plus additional years of regular playing), which had a strong association with years of music lessons, $r = .94$, $p < .001$. Participants were also asked about their age, ethnicity, linguistic background, and family income, as well as their parents' education, ethnicity, and linguistic backgrounds. Family income and parents' education were quantified as in Study 1.

Criterion variables included measures of intelligence and academic achievement. Each student was administered the complete Wechsler Adult Intelligence Scale—Third Edition (WAIS–III), which has good reliability and validity (Wechsler, 1997). The WAIS–III is similar to the WISC–III but appropriate for testing participants 16 years of age or older. The WAIS–III has 14 subtests, 11 of which are used to form four index scores: Verbal Comprehension (subtests: Vocabulary, Similarities, and Information), Perceptual Organization (subtests: Picture Completion, Block Design, and Matrix Reasoning), Working Memory (subtests: Arithmetic, Digit Span, and Letter-Number Sequencing), and Processing Speed (subtests: Digit–Symbol Coding and Symbol Search). FSIQ is formed from a slightly different combination of 11 subtests (adding Picture Arrangement and Comprehension but excluding Symbol Search and Letter–Number Sequencing). We also administered an optional subtest, Object Assembly, because it is a measure of spatial–temporal ability. High school average, based on self-report, served as a measure of academic achievement. Although self-report measures can be subject to bias and inaccuracy, most participants had graduated from high school less than a year previously.

Table 4
Correlations Among Predictor Variables (Upper) and Criterion Variables (Lower) in Study 2

Predictor variables	1	2	3	4
1. Playing music regularly	—	.03	.16*	−.02
2. Family income		—	.19**	.16*
3. Parents' education			—	.02
4. Gender				—

Criterion variables	1	2	3	4	5	6	7
1. FSIQ	—	.97†	.81†	.77†	.62†	.43†	.39†
2. IQ-PC		—	.74†	.81†	.68†	.51†	.41†
3. Verbal Comprehension			—	.42†	.36†	.11	.34†
4. Perceptual Organization				—	.40†	.42†	.23†
5. Working Memory					—	.32†	.32†
6. Processing Speed						—	.35†
7. High school average							—

Note. Playing music regularly is measured in years. Gender is dummy-coded (men = 1, women = 0). WAIS–III scores are based on Canadian norms.
* $p < .1$. ** $p < .05$. † $p < .01$.

Results and Discussion

Preliminary analyses. Descriptive statistics for the WAIS–III are provided in Table 1. FSIQ and index scores were higher than average, as one would expect from a sample of college students. (As in Study 1, Canadian norms were used. With U.S. norms, mean FSIQ was 110.4, $SD = 11.9$). High school grades were also high on average ($M = 81\%$, $SD = 6\%$). Principal components analysis of the 14 WAIS–III subtests revealed that a one-factor solution accounted for 33% of the total variance, with each subtest loading positively on the principal component (highest: Block Design, $r = .68$; lowest: Digit Span, $r = .39$). As in Study 1, factor scores on the IQ-PC were used as a measure of general intellectual ability, in addition to FSIQ.

Associations among the predictor (upper matrix) and criterion (lower matrix) measures are provided in Table 4. Gender was included as a predictor but age was not because age had no association with any other variable. Family income and parents' education were not predictive of years of playing music regularly (the correlation was marginal for parents' education), but parents' education was associated positively with family income. Correlations among criterion variables confirmed that WAIS–III measures were significantly intercorrelated (with one exception) and that they were associated positively with high school average.

Principal analyses. FSIQ from one student was almost four standard deviations above the regression line when IQ was regressed on playing music regularly. The student was excluded from subsequent analyses.[4] Otherwise, scatter plots revealed no violations of linearity. Simple and partial correlations between the predictor and criterion variables are provided in Table 5. As predicted, the associations were smaller in magnitude and less consistent than those observed in Study 1. Specifically, a longer history of playing music regularly was correlated positively with FSIQ[5] and IQ-PC, two of four index scores (Perceptual Organization and Working Memory), and high school average. Individual differences in playing music accounted for 4% of the variance in FSIQ, 5% of the variance in IQ-PC, and 5% of the variance in high school average. These associations remained significant after partialing out individual differences in parent's education, family income, and gender, with playing music accounting for 4%, 5%, and 4% of the remaining variance in FSIQ, IQ-PC, and high school average, respectively.

More detailed analyses revealed that correlations between playing music regularly and the individual subtests were also somewhat inconsistent—statistically significant ($p < .05$) for three (Similarities: $r = .21$, Digit Span: $r = .17$, and Object Assembly: $r = .23$) and positive but nonsignificant for 10 of the other 11. Nonetheless, the probability of observing 10 out of 11 positive associations due to chance was remote if the null hypothesis were true in each case ($p < .05$; sign test). When general intelligence (as measured by IQ-PC) was held constant, none of the partial associations between playing music and the WAIS–III subtests or index scores was significant. In line with the results from Study 1, the partial association between high school average and playing music remained marginal when general intelligence was held constant ($pr = .15$, $p = .075$).

Parents' education had significant simple associations with Verbal Comprehension and high school average, but the partial association was significant only for Verbal Comprehension. Family income was not associated with any of the criterion measures.

[4] The principal findings were identical but weaker when the outlier was included in the analyses. Specifically, FSIQ was associated positively with playing music regularly ($r = .18$, $p < .05$), even when family income, parents' education, and gender were held constant ($pr = .17$, $p < .05$).

[5] Years of music lessons also had a small but significant correlation with FSIQ ($r = .18$, $p < .05$).

Table 5
Simple Correlations (and Partial Correlations in Parentheses) Between Predictor and Criterion Variables in Study 2

Criterion variable	Predictor variable: Playing music regularly	Family income	Parents' education
FSIQ	.21** (.21**)	.00 (−.05)	.11 (.10)
IQ-PC	.23† (.22†)	.03 (−.02)	.13 (.11)
Verbal Comprehension	.15* (.12)	.07 (.01)	.19** (.17**)
Perceptual Organization	.18** (.19**)	−.02 (−.04)	.02 (.01)
Working Memory	.17** (.17**)	.02 (−.01)	.13 (.11)
Processing Speed	.12 (.16*)	−.08 (−.05)	−.15* (−.14*)
High school average	.22† (.19**)	.07 (.06)	.17** (.14)

Note. Among the undergraduate participants, one outlier was excluded. Partial correlations were calculated with the other predictors (as well as gender) held constant. WAIS–III scores are based on Canadian norms.
* $p < .1$. ** $p < .05$. † $p < .01$.

Summary. Taking music lessons in childhood was a significant predictor of IQ in young adulthood and of academic ability in high school. Specifically, playing music regularly had small but significant associations with FSIQ, IQ-PC, Perceptual Organization, Working Memory, and high school average, and these associations remained significant after holding constant individual differences in family income, parents' education, and gender.

General Discussion

Two correlational studies tested the possibility of an association between taking music lessons and IQ. The findings indicated that (1) duration of music lessons in childhood was associated positively with IQ (Studies 1 and 2), (2) the association was small but it extended to IQ in early adulthood (Study 2), (3) the association was general rather than limited to a specific subset of intellectual abilities (Studies 1 and 2), (4) the association extended to academic achievement (Studies 1 and 2) even when individual differences in general intelligence were held constant (Study 1), (5) the association did not extend to measures of social functioning (Study 1), and (6) nonmusical out-of-school activities did not have similar associations with intellectual performance (Study 1). Let us return now to the questions that motivated the present report.

Is there a significant association between music and intelligence? The present findings are positive in this regard. Previous correlational (Bilhartz et al., 2000; Brandler & Rammsayer, 2003; Brochard et al., 2004; Butzlaff, 2000; Chan et al., 1998; Cheek & Smith, 1999; Gromko & Poorman, 1998; Hetland, 2000; Ho et al., 2003; Hurwitz et al., 1975; Jakobson et al., 2003; Orsmond & Miller, 1999; Vaughn, 2000) and experimental (Gardiner et al., 1996; Rauscher, 2002; Rauscher et al., 1993; Schellenberg, 2004) studies have reported associations between music lessons and intellectual functioning. The present study uncovered a "dose–response" association, with longer duration of musical training predictive of better intellectual functioning. The findings also confirmed that real-world associations between music lessons and intelligence cannot be attributed solely to potential confounding variables such as parents' education or family income. Nevertheless, the observed associations could still be an artifact of a third variable (or set of variables) that was not measured in the present study.

The generalizability of the present findings is limited, moreover, by the nonrandom sampling methods. In Study 1, the child participants were from volunteer families. As such, they may have differed systematically from the local community. It is almost impossible, however, to recruit a random sample in a study of this type, and concerns about sampling bias are alleviated somewhat because the sample mirrored the diverse cultural and socioeconomic mix of the local area. In Study 2, problems of generalizability are identical to those of any study conducted with samples of undergraduates registered in an introductory psychology course. The primary concern here is one of an interaction, specifically that the association between music lessons and intellectual functioning would vary depending on the makeup of the sample. Although this is a serious concern and a definite possibility, the literature provides no motivation for predicting such an interaction. Moreover, range restrictions and reduced variance relative to the general population (see *SD*s in Table 1) likely made observed associations smaller than they otherwise would have been.

Are observed associations limited to specific subsets of intellectual ability (e.g., mathematical, spatial–temporal, verbal)? The present findings are negative in this regard. Previous reports have identified links between musical training and a wide variety of intellectual abilities (for reviews, see Schellenberg, 2003, 2005, 2006). In each case, the outcome measures tested specific aspects of cognitive functioning. But evidence of a link between music lessons and, say, mathematical ability (Vaughn, 2000) tells us nothing about whether music lessons would also be associated with verbal abilities, spatial abilities, or intelligence in general. The present study was the first to use entire IQ tests as the primary criterion measures. In Study 1, associations with musical training were evident across the IQ subtests, index scores, and aggregate measures (FSIQ or IQ-PC). Associations with music lessons were also evident across different aspects of academic ability—measured either with a standardized test (Mathematics, Reading, and Spelling) or with grades in school (Mathematics and Language Arts)—but music lessons were not associated with measures of social functioning. In Study 2, playing music regularly in childhood was associated with the measures of general intelligence, high school average, and two of the four IQ index scores. Associations between playing music and the individual WAIS–III subtests were also very small but general.

These response patterns provide evidence that is at odds with each of the specific-link hypotheses. They also provide evidence that is relevant to debates about the structure of intelligence. They are consistent with the proposal that a general factor, *g*, underlies performance across a wide variety of intellectual measures (Carroll, 1993). From this perspective, even though Wechsler's (1991, 1997) measure of general intelligence (i.e., FSIQ) is calculated as the sum of specific abilities, *g* is actually the backbone of performance across subtests. In other words, general intelligence is better conceptualized as the driving force that predicts virtually all abilities, rather than the aggregate total of specific abilities. Several aspects of the present results provide support for this view. First, principal components analysis in both studies indicated that a single factor could account for a substantial proportion of the variance in the original subtests. Second, music lessons were associated with performance across the IQ subtests. Third, the absolute magnitude of associations with music lessons and specific measures of ability (i.e., subtests or index scores) never exceeded the magnitude of the associations with the purest measure of *g* (the IQ principal component). Fourth, when general ability was held constant, associations between music lessons and specific subsets of intelligence disappeared.

Are the associations large enough to have practical significance? Statistically significant correlations ranged from a high of .36 (Study 1: simple association between duration of music lessons and IQ-PC) to a low of .17 (Study 2: simple and partial associations between duration of playing music regularly and Working Memory). In Study 1 (children), each additional month of music lessons was accompanied by an increase in FSIQ of approximately one sixth of a point ($b = .156$, $SE = .052$), after partialing out effects of parents' education, family income, nonmusical activities, and age. In Study 2 (undergraduates), each additional year of playing music regularly was accompanied by an increase in FSIQ of one third of a point ($b = .333$, $SE = .134$), after partialing out effects of parents' education, family income, and gender. In childhood, then, six years of lessons (assuming 8 months of lessons per year) was associated, on average, with an increase in FSIQ increase of approximately 7.5 points, which is half a standard deviation and far from trivial. But the same 6 years of playing music regularly in childhood were predictive of an increase in FSIQ of only 2 points in early adulthood. In other words, short-term associations were stronger than long-term associations, which is in line with other findings indicating that associations between cognitive functioning and environmental factors decline throughout childhood and adolescence (Plomin et al., 1997).

In Study 1, individual differences in duration of music lessons accounted for approximately 12% of the variance in criterion measures of intelligence and academic performance. Because of overlap between taking lessons and extraneous variables (i.e., family income, parents' education, nonmusical activities, age), the explanatory power of music lessons was reduced to approximately 6% after these other variables were held constant. In Study 2, even after accounting for potential confounding variables, playing music regularly in childhood continued to account for approximately 4% of the variance in intellectual functioning in early adulthood. On the one hand, then, it is clear that musical training accounts for a relatively small portion of intellectual abilities, with the vast bulk of variance being independent of musical involvement. On the other hand, the role of IQ in everyday life is profound (Gottfredson, 1997, 2002), which means that even small effect sizes involving IQ are potentially important if the associations are causal. For example, we know that childhood IQ is predictive of school grades, academic achievement, and occupational status (Gottfredson, 1997, 2002; Neisser et al., 1996), even occupational status at age 50 (Deary et al., 2005). Childhood IQ is also predictive of longevity, including the likelihood of getting cancer or cardiovascular disease in adulthood, even after accounting for individual difference in socioeconomic status (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Gottfredson & Deary, 2004).

To put the findings in a larger context, it is important to note that nonmusical activities could have different associations that are as appealing as the ones between musical activities and intellectual performance. For example, there is evidence that drama lessons facilitate adaptive social behaviors but music lessons do not (Schellenberg, 2004), and direct benefits to physical health would obviously be greater from playing sports than from music or drama lessons. Children cannot be involved in every out-of-school activity that is potentially good for them, but a reasonable amount of extracurricular activities may enrich a child's development in numerous ways.

If we observe an association between music lessons and intelligence, how can we explain the association? As noted, the design of the present study does not allow for inferences of causation. Accordingly, explanations involving both causal directions will be considered, as well as the possibility that the observed associations are driven by a third factor.

One possible explanation is that individual differences in IQ influence the likelihood that a child takes music lessons. Indeed, the observed associations between musical training and general intelligence (*g*) are consistent with this view because *g* is considered to be "less malleable than more specific abilities" (Carroll, 1993, p. 686). More specifically, high-IQ children (and/or their parents) could be more motivated than other children. Thus, taking music lessons and playing music regularly for extended periods of time could be a consequence of motivation. Although this explanation is appealing in its simplicity, links between IQ and motivation in other domains (e.g., school in general, mathematics problems in particular, information-processing tasks, monetary gain, economic and professional status) tend to be weak or nonexistent (Battle, 1965; Cassidy & Lynn, 1991; Gagné & St. Père, 2002; Larson, Saccuzzo, & Brown, 1994; Paule, Chelonis, Buffalo, Blake, & Casey, 1999). It is also possible that high-IQ children enjoy music lessons more than their lower-IQ counterparts because they find it easier to read musical notation, to identify patterns in musical stimuli (e.g., themes and variations, verses and choruses, harmonic progressions), and so on. In other words, high-IQ children may have more mental capacity to take music lessons as well as go to school because both activities are cognitively demanding. Although this perspective can account for the present findings as well as for previous correlations between music lessons and intellectual functioning, it cannot explain previous experimental findings (e.g., Gardiner et al., 1996; Schellenberg, 2004).

Other explanations assume that the causal direction flows from music lessons to intelligence. The second explanation is based on the well-known finding that schooling increases IQ (Ceci, 1991; Ceci & Williams, 1997). School instruction is particularly effective when classes are small (Ehrenberg, Brewer, Gamoran, & Wilms, 2001; NICHD Early Child Care Research Network, 2004), and music lessons are typically taught individually or in small groups. By simply exaggerating the schooling effect, music lessons would be sufficient but not necessary as a means to enhance IQ. Other out-of-school activities that are school-like and taught in small groups could have similar effects. (*School-like* here refers to cognitive, adult-supervised activities that require serious and concerted effort on the part of the participant in order to acquire knowledge.) Drama lessons are similar in many respects to music lessons (i.e., memorization, rehearsal, expression of emotions, and so on), but their lack of an association with intellectual abilities (Schellenberg, 2004) could be a consequence of the fact that drama includes activities that are typical of children's play, such as make-believe and dressing up. Other activities that seem intuitively more cognitive and school-like, such as reading, math, or chess lessons, could have associations with IQ that are similar to those of music lessons. Although the families in Study 1 were asked to provide detailed information about all of their child's out-of-school activities, nonmusical scholastic activities were rare in our sample, which limited power to uncover an association with IQ. From this perspective, the association between IQ and music lessons would not be attributable to music per se. Music lessons may still be distinctive as an out-of-school activity, however, because they are school-like yet relatively enjoyable and common in Western society. Further evidence of an affinity between music lessons and schooling is provided by the observed associations between music lessons and academic performance, which remained evident (i.e., significantly in Study 1, marginally in Study 2) when effects of general intelligence were held constant.

A third possibility is that taking music lessons is akin to learning a second language. Music has rules of order that are similar to those of syntax in language (Koelsch, 2005; Lerdahl, 2001; Lerdahl & Jackendoff, 1983; Patel, 2003), and similar mechanisms are likely to be involved in the acquisition of musical and linguistic knowledge (McMullen & Saffran, 2004). Moreover, a culture's linguistic rhythms and pitch intervals are predictive of its musical rhythm (Patel & Daniele, 2003) and pitch (Patel, Iversen, & Rosenberg, 2004) patterns. Music and language differ most dramatically in the way they are thought to convey meaning. Words are linked to concepts in semantic memory, whereas music is typically considered to be a language of emotions (Janata, 2004). This distinction may be somewhat exaggerated because unfamiliar musical passages have been shown to prime concepts in semantic memory, just as words do (Koelsch et al., 2004). If music's similarity to language were the source of the association between music lessons and cognitive abilities, however, one would expect cognitive advantages of music lessons to parallel those of bilingualism (Bialystok, 1999, 2001; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok & Martin, 2004; Craik & Bialystok, 2005), which are evident for control processes (i.e., fluid intelligence) but not for acquired knowledge (i.e., crystallized intelligence). In the present study, associations with music lessons extended to control processes (as measured by Working Memory, Perceptual Organization, and Processing Speed) as well as to world knowledge (as measured by Verbal Comprehension and academic achievement).

A fourth possibility is that specific features of music lessons give them special status as an out-of-school activity. In other words, children who take music lessons may have experiences that differ qualitatively from those of other children. Music lessons involve focused attention for long periods of time; regular (often daily) practice; learning to decode complex patterns of visual symbols (i.e., reading music); memorizing extended passages and entire pieces; learning about rules of pattern formation that define Western musical structures (including intervals, scales, chords, and chord progressions); incremental improvement of fine motor skills (typically involving the fingers or the vocal apparatus); and learning to express emotions through music, both obviously (e.g., with large fluctuations in amplitude or tempo) and subtly (e.g., with small deviations in timing or pitch). Music's association with IQ and academic performance could be the consequence of a single feature, a subset of these features, or the complete array of skills that music lessons foster. Nonetheless, if one particular aspect of music lessons (e.g., learning to read musical notation) were the primary source of the association between music lessons and intellectual abilities, one would expect some of the narrower subtests in IQ batteries (e.g., the visual pattern-matching skills measured by the Symbol Search or Coding subtests) to be enhanced more than others. The generality of the associations between music lessons and the various facets of IQ implies the involvement of multiple factors.

A fifth explanation suggests that the stimulus properties of music, rather than musical activities, are driving the effect. Music requires listeners and performers to attend to multiple dimensions (e.g., pitch, rhythm, timbre, volume) structured hierarchically. Because musical tunes are defined by relational rather than absolute information about pitch and rhythm, they retain their identity across variations in pitch height, tempo, timbre, and volume. Thus, musical structures are abstractions that generalize widely across a variety of transformations. Mental representations of music must be sufficiently abstract to allow for recognition of similarities between patterns that vary relationally as well as absolutely, as in the case of "theme and variations." For example, a recognizable motive is repeated in the first two measures of Beethoven's Fifth Symphony, yet the absolute pitch level and the pitch relations change from the first to the second measure. Formal exposure to music could promote the ability to recognize pattern regularities and to think flexibly. These abilities are considered to be central to *g* (Carroll, 1993; Spearman, 1927) as well as to alternative concepts of intelligence (e.g., Sternberg, 1985).

A sixth and final explanation holds that observed associations between music lessons and intellectual ability were artifacts of a third variable or set of variables. The most likely candidate would be parents' IQ, which was only partially accounted for by measuring parents' education. To illustrate, the correlation between IQ and years of education is about .55 (Neisser et al., 1996), which means that only about 30% of the variance in parents' IQ was accounted for in the present study. In principle, the remaining 70% could account for individual differences among the present participants in IQ and in duration of musical involvement. It is less likely, however, that parents' IQ could account for the association between music lessons and academic performance that was independent of general intelligence. Moreover, parents' IQ cannot account for the positive results of a controlled experiment that included random assignment of young children to music lessons (Schellenberg, 2004).

Explanations of observed associations between music lessons and intellectual functioning are not necessarily mutually exclusive. In fact, future empirical efforts could find that there is no clear winner or loser. All or most of the proposed explanations could be correct to some degree because the underlying mechanisms might prove to be complex and interactive, perhaps even circular (Schellenberg, 2005). For example, parents with high IQs tend to have children with high IQs (Plomin et al., 1997), who could be more likely than other children to undergo extended training in music, which could exaggerate individual differences in intellectual functioning. The true nature of the association between music lessons and intellectual abilities can be clarified only by future research.

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