CHAPTER 6

EXPOSURE TO MUSIC: THE TRUTH ABOUT THE CONSEQUENCES

E. GLENN SCHELLENBERG

In this chapter, I examine claims about non-musical consequences of exposure to music. Over the past 10 years, the possibility that *music makes you smarter* has sparked the imagination of researchers, the popular press, and the general public. But is there any truth to this idea? If so, what is the evidence? My goal here is to answer these questions as well as possible by reviewing the relevant scholarly literature.

At the outset, we might ask why people care about non-musical side-effects of exposure to music. Do we have similar concerns about other subjects taught in school and university, such as mathematics, English, or chemistry? Would we value physics *less* if we knew that it did *not* lead to improvements in drama? Although the question is tongue-in-cheek, it highlights the fact that all academic disciplines are not considered equal. In my view, the most likely explanation for the disparity is that music is both an art form *and* an academic discipline. Somehow, its status as an art form reduces its status as a discipline. Studying fine arts is considered to be icing on the cake in a typical scholarly meal, whereas mathematics and science are the meat and potatoes. As such, music is more likely than other subjects to be eliminated from the school curriculum when budgets are reduced. Indeed, in the neo-conservative, belt-tightening climate of the late twentieth century, music education programmes were often slashed or threatened. Consequently, the idea that music might have collateral benefits was welcomed with open arms as a way of saving or reviving programmes. It suggested that music could be *more* than just an art form. In fact, music could be a conduit for improvements in other domains.

These historical and contextual factors helped to exaggerate the timeless and universal appeal of quick fixes to complex problems. Competition for admission to the best schools and universities is stiff, and a few extra IQ points could make an important difference. It is also well known that IQ is predictive of academic performance, job performance, income, health, longevity, and dealing successfully with the demands of everyday life (e.g., Brody, 1997; Ceci & Williams, 1997; Gottfredson, 1997; Sternberg *et al.*, 2001; Deary *et al.*, 2004; Gottfredson & Deary, 2004). Thus, it is no wonder that the public and the media paid attention to the proposal that simply exposing oneself to music leads to a boost in IQ. It is difficult to imagine a simpler fix (music) to such a complex problem (intelligence).

In Western society, exposure to music typically takes one of two forms: listening and performing. Music listening is everywhere, both by design and by accident. People buy CDs, they watch and hear music videos on TV, they listen to music on the radio, they download

MP3 files from the internet, and they attend concerts. They also *overhear* music in shopping malls, at the dentist, from the neighbour's home or car, and so on. By contrast, performing music is relatively rare in Western society. Many children take lessons for a year or two. Only a relatively small minority study music year in and year out, practising regularly on a daily basis. Moreover, the stark contrast between simply listening to music on the one hand, and actively pursuing a musical education or performing music regularly on the other hand, makes it highly unlikely that the two activities would have similar effects on non-musical aspects of human behaviour. As I have argued previously (Schellenberg, 2001, 2003), it is important to treat these two forms of exposure to music separately. Accordingly, the first section of this chapter examines consequences of music listening. The second section examines consequences of music lessons and performing.

Music listening

Current interest in side-effects of exposure to music stems largely from the publication of an article in *Nature* in 1993 (Rauscher *et al.*, 1993). The researchers tested the spatial abilities of undergraduates after 10 minutes of exposure to classical music, relaxation instructions, or silence. The tests were three subtests from the Stanford-Binet Intelligence Scale (Thorndike *et al.*, 1986), a widely used test of IQ. Performance on the spatial tests proved to be better after listening to music than in the other two conditions. Because the musical piece was a recording composed by Mozart, the effect became known as the *Mozart effect*. It is important to note that the effect was short-lived, as one would expect from simply listening to music for a mere 10 minutes. In fact, although each participant completed all three spatial tests after the exposure phase, the advantage for the Mozart group was evident only on the first test.

Why did the findings create such a fuss? One likely reason is that the authors reported their results as IQ scores, which the media translated as revealing a very simple fix to a complex problem, namely that listening to Mozart increases intelligence. Another reason is that the authors did not consider well-established findings from psychology or neuroscience to explain the link between music listening and test performance. Instead, they suggested that passive listening to 'complex' music (e.g., the Mozart piece they used as a stimulus) enhances abstract reasoning in general, including spatial reasoning. In other words, they proposed a direct causal link between listening to Mozart and spatial abilities, which the media extended to intelligence in general.

Researchers subsequently tried to replicate and extend the effect using a variety of outcome measures and different pieces of music. They were successful in some instances but not in others (for reviews, see Chabris, 1999; Hetland, 2000b). For example, performance on the original tests of spatial abilities was found to improve after listening to music composed by Mozart (Rauscher *et al.*, 1995; Rideout & Laubach, 1996; Rideout & Taylor, 1997; Rideout *et al.*, 1998) or by Yanni, a New Age composer (Rideout *et al.*, 1998), but not after listening to minimalist music composed by Philip Glass (Rauscher *et al.*, 1995). Other researchers found no effect of listening to Mozart on a test of working memory (Steele *et al.*, 1997), on an alternative test of spatial abilities (Carstens *et al.*, 1995), or on tests of abstract reasoning (Stough *et al.*, 1994; Newman *et al.*, 1995).

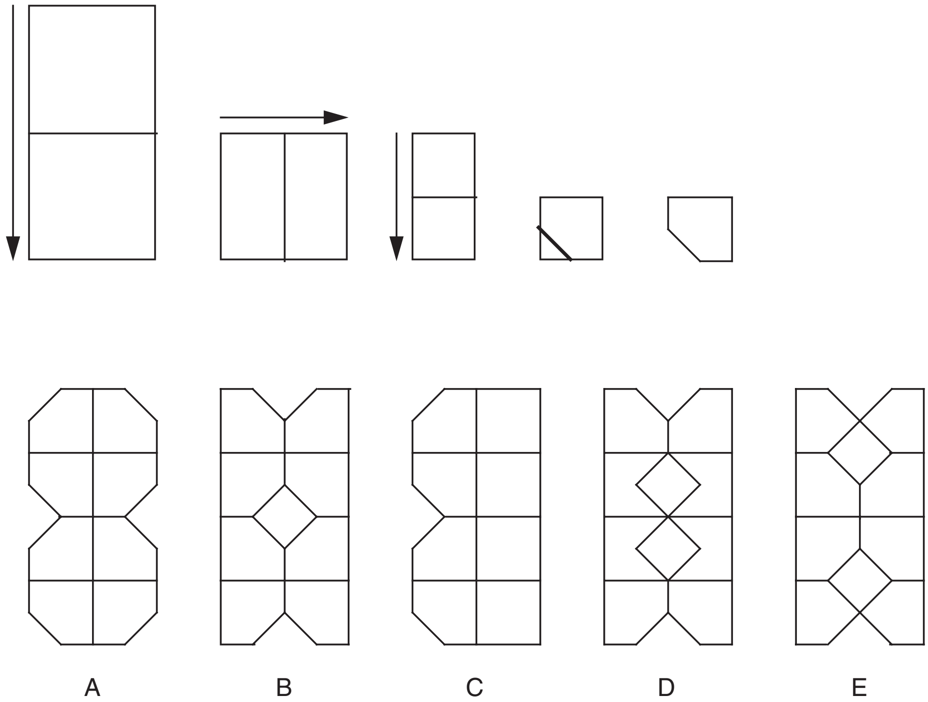

Figure 6.1 An example of a test item similar to those on the paper-folding-and-cutting test of spatial abilities. The upper portion illustrates folding and cutting manipulations to a rectangular piece of paper. The respondent chooses the option in the lower portion that corresponds to the paper after it is unfolded. The correct answer is B.

In order to explain the discrepant results, Rauscher and her colleagues (Rauscher *et al.*, 1995; Rauscher & Shaw, 1998) narrowed the scope of the proposed causal link between music listening and abstract reasoning. Their revised hypothesis limited the effect to tests of *spatial-temporal* abilities, those requiring 'mental imagery and temporal ordering' (Rauscher, 1999, p. 827). Only one of the three subtests from their original article met this new criterion: *paper-folding-and-cutting* (PF&C). The PF&C test illustrates folding and cutting manipulations performed on a rectangular piece of paper (see Figure 6.1). Participants choose which of five alternatives corresponds to the piece of paper when it is unfolded. Their final score is the total number of correct responses. Re-analysis of the original results from 1993 showed that the Mozart effect was reliable only for this particular test (Rauscher & Shaw, 1998). None the less, some researchers have failed to replicate the effect even when they used this particular outcome measure (Steele *et al.*, 1999a–c). These null findings suggest that the effect is fleeting or highly sensitive to minor procedural differences.

With a somewhat different approach, my colleagues and I (Nantais & Schellenberg, 1999; Thompson *et al.*, 2001; Husain *et al.*, 2002; Schellenberg & Hallam, 2005; Schellenberg *et al.*, in press) conducted a series of studies that sought to (1) replicate the original effect, and (2) make systematic alterations to the method in order to highlight the underlying mechanisms driving the effect. The first study (Nantais & Schellenberg, 1999) consisted of two experiments. In the first, participants were college undergraduates tested on two occasions with alternate versions of the PF&C task that were equivalent in difficulty. The students completed the tests in a sound-attenuating booth after listening to music or sitting in silence for 10 minutes. The music was the same Mozart piece used by Rauscher *et al.* (1993) or another piece composed by Schubert from the same CD (i.e., with the same performers, recording quality, and so on). Both groups of students had higher scores on the PF&C test after listening to music than after sitting in silence (see Figure 6.2, upper panel).

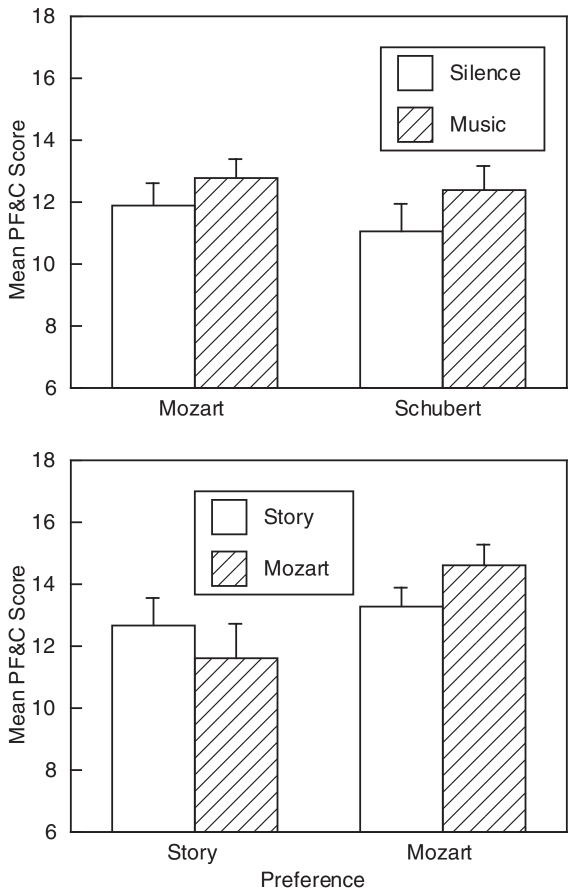

Figure 6.2 Results from Nantais and Schellenberg (1999) experiments 1 (upper) and 2 (lower). The upper panel illustrates that performance on the paper-folding-and-cutting (PF&C) test was better after listening to music composed by Mozart (left) or Schubert (right) than after sitting in silence. In the lower panel, Mozart was contrasted with a narrated story. Performance on the PF&C task was better after listening to the story for participants who preferred the story (left), but after listening to Mozart for those who preferred Mozart (right). Error bars are standard errors.

In other words, we replicated the Mozart effect and found a Schubert effect that was similar in magnitude.

The results from this first experiment left it unclear, however, whether the effect was due to music listening *per se*, or because the music conditions were simply more interesting than sitting in silence. In the second experiment (same procedure and equipment), we contrasted listening to Mozart with listening to a narrated story. Both conditions had auditory stimuli, with the story selected to be about as interesting as listening to Mozart. The logic was that if the effect was actually due to *music* listening, it should also be evident when the control condition consisted of an auditory but non-musical stimulus. This time, however, the advantage for Mozart disappeared. The participants were also asked which stimulus they preferred (the music or the story). Further analysis of the data revealed that performance varied reliably as a function of preference (see Figure 6.2, lower panel). Those who preferred Mozart did better on the PF&C test after listening to Mozart. Those who preferred the story did better after listening to the story. The results indicated that the so-called Mozart effect is not specific to Mozart in particular or to music in general. Moreover, it seems highly likely that the positive effects of music in experiment 1 were a consequence of the fact that participants preferred listening to music over sitting in silence.

In a second study (Thompson *et al.*, 2001), we explored the idea of listeners' preferences in greater detail. We hypothesized that preferences in the initial study were related to differences in emotional states, particularly listeners' arousal levels and moods. Music is known to have reliable effects on listeners' emotional states (Thayer & Levenson, 1983; Krumhansl, 1997; Gabrielsson, 2001; Peretz, 2001; Schmidt & Trainor, 2001; Sloboda & Juslin, 2001), and people listen to music precisely for its emotional impact (Sloboda, 1992). Arousal (i.e., how alert or fatigued one feels) and mood (i.e., how positive or negative one feels) correspond to the two dimensions of emotions described by a well-known theory of emotions (Russell, 1980). Effects of arousal and mood on test performance are well established (Isen *et al.*, 1992; Khan & Isen, 1993; Cahill & McGaugh, 1998; Dutton & Carroll, 2001; Cassady & Johnson, 2002; Eich & Forgas, 2003; Grawitch *et al.*, 2003). According to the *arousal and mood hypothesis*, the 'special link' between music composed by Mozart and spatial (or spatial-temporal) abilities is actually just one example of a stimulus that affects arousal and mood, which, in turn, affect performance on a wide variety of tests. The main advantage of this perspective is that it explains the seemingly mysterious Mozart effect in a straightforward manner with well-established psychological findings.

As in Nantais and Schellenberg (1999), undergraduates came to the lab on two occasions. They completed the PF&C test after listening to music on one occasion, and after sitting in silence on the other. For half of the participants, the music was the same Mozart sonata used previously. The sonata is an up-tempo, happy sounding piece in a major key. For the other half, the music was Albinoni's Adagio—a slow-tempo, sad sounding piece in a minor key that is often played at funerals. On both visits, arousal and mood were measured at the beginning and the end of the testing session. Compared with the baseline (i.e., silence) condition, we expected that the Mozart piece would increase arousal levels and improve listeners' mood, whereas the Albinoni piece should decrease arousal and worsen mood.

Figure 6.3 Results from Thompson *et al.* (2001) illustrating that performance on the paper-folding-and-cutting (PF&C) task was better after listening to Mozart compared with sitting in silence (left), but not after listening to Albinoni (right). Error bars are standard errors.

Accordingly, we also predicted that we would find a music advantage on the PF&C test for the Mozart group but not for the Albinoni group. The data were completely consistent with these predictions (see Figure 6.3). Moreover, when we used statistical means to hold constant participants' changes in arousal and mood, the Mozart advantage on the PF&C task disappeared.

In a third study (Husain *et al.*, 2002), we examined which features of the Mozart sonata led to changes in arousal and mood, which, in turn, led to enhanced performance on the PF&C task. We created four versions of the same Mozart piece that varied in tempo (fast or slow) and mode (major or minor). Undergraduates heard one of the versions and then completed the PF&C task. Arousal and mood were measured at the beginning and end of the testing session. As expected, performance on the PF&C task was better among listeners who heard the fast rather than slow versions, and for those who heard the major rather than the minor versions (see Figure 6.4). Another interesting finding was that the tempo and mode manipulations had different effects on arousal and mood. The tempo manipulation influenced arousal but not mood, whereas the mode manipulation influenced mood but not arousal. As in Thompson *et al.* (2001), changes in arousal and mood accounted for most of the variance in PF&C scores (i.e., whether participants performed well or poorly), with higher scores associated with higher levels of arousal and more positive moods.

In the fourth study in this series (Schellenberg *et al.*, in press), we attempted to find the few missing pieces of evidence that were needed to support the arousal and mood account of the Mozart effect. Our goals were to show that the Mozart effect generalized to (1) tests that do not measure spatial-temporal abilities, and (2) any type of music that is enjoyable for the particular group of listeners. To this end, we conducted two experiments. In the first, undergraduates listened to the Mozart piece on one

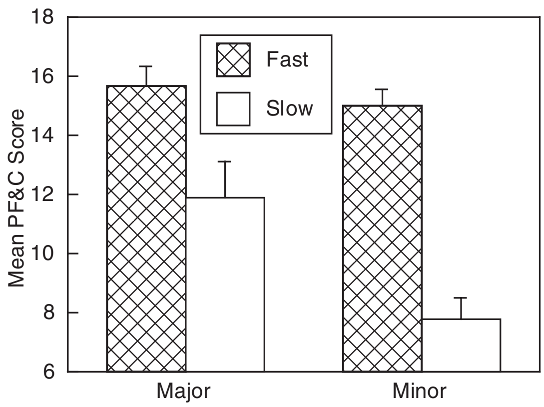

Figure 6.4 Results from Husain *et al.* (2002) illustrating performance on the paper-folding-and-cutting (PF&C) task after listening to one of four versions of a Mozart sonata. Performance was better after the fast compared with the slow versions, and after the major compared with the minor versions. Error bars are standard errors.

visit to the laboratory and the Albinoni piece on another visit. Instead of administering the PF&C test, we administered two subtests from the Wechsler Adult Intelligence Scale—Third Edition (Wechsler, 1997), one on each visit. Neither subtest measured spatial-temporal abilities. One (Symbol Search) was a speeded test of pattern recognition. The other (Letter–Number Sequencing) was a measure of working memory. Testing order of the music (Mozart then Albinoni or vice versa) was counterbalanced with testing order of the particular subtest (Symbol Search then Letter–Number Sequencing or vice versa). Arousal and mood were measured at the beginning and the end of both testing sessions.

At the first test session, the different music-listening experiences had a small effect on mood (i.e., moods were more positive after listening to Mozart than to Albinoni) but no effect on arousal. Perhaps the testing environment (sitting in a sound-attenuating booth wearing headphones) was too unusual for this particular group of listeners for the music to have much of an arousing effect. At the second session, however, we found reliable differences in arousal *and* in mood as a consequence of music listening, with increases in arousal and positive mood after listening to Mozart, but decreases in arousal and positive mood after listening to Albinoni. Because music listening affected arousal *and* mood at the second session but only mood at the first session, we expected that music listening would have a stronger impact on performance on the IQ subtests at the second test session compared with the first. Indeed, at the first session, music listening did not affect performance on the IQ subtests. At the second session, however, we found a reliable difference for one of our two outcome measures (see Figure 6.5). Performance on the Symbol Search subtest was better after listening to Mozart than after listening to Albinoni. In short, when there was a reliable difference in arousal and in mood as a consequence of music listening, there was

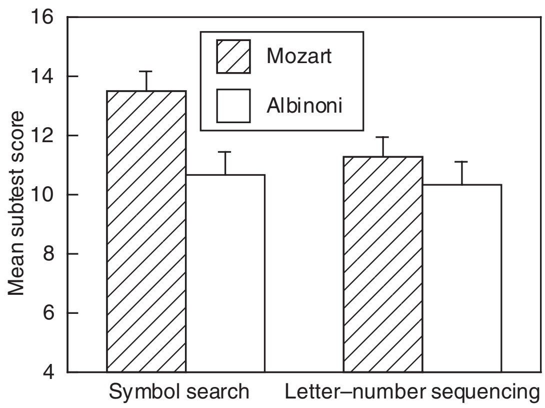

Figure 6.5 Results from experiment 1, Schellenberg *et al.* (in press), illustrating that performance on the symbol search subtest was better after listening to Mozart than to Albinoni (second test session). The Mozart advantage on the letter–number sequencing subtest was not significant. Error bars are standard errors.

also a reliable difference on one of the IQ subtests. When there was no difference in arousal, there was no evidence of a Mozart effect.

In a second experiment (Schellenberg *et al.*, in press), we sought to generalize the findings even further by examining the creative abilities of Japanese 5-year-old children. Each child was provided with paper and 18 crayons and asked to make a drawing after a lunch break that included exposure to music. The outcome measures were time spent drawing (relative to a baseline measure), as well as judgements of creativity that adults made for the drawings. Exposure to music consisted of listening to the Mozart or the Albinoni piece (used earlier) during lunch, listening to familiar children's songs during lunch, or singing children's songs for 20 minutes after lunch. For young children, we doubted that listening to classical music (i.e., Mozart or Albinoni) would optimize arousal and mood. Rather, hearing or singing familiar songs would be more likely to do so. In line with this view, the results revealed that (1) the children spent a longer time drawing after exposure to familiar music compared with classical music (Figure 6.6, upper), and (2) creative ratings were higher for the drawings the children made after exposure to familiar music (Figure 6.6, lower). In a separate investigation, we (Schellenberg & Hallam, 2005) showed that cognitive benefits are more likely after 10- and 11-year-olds listen to popular music than to Mozart.

To summarize, the results from this series of studies make it clear that specific characteristics of music affect arousal and mood, which, in turn, affect performance on cognitive tasks. In one sense, then, the Mozart effect describes a reliable phenomenon. The term is misleading, however, because the effect does not depend on listening to Mozart, or even on listening to music. Moreover, the claim of a specific causal link between listening to music composed by Mozart and spatial-temporal abilities is without merit.

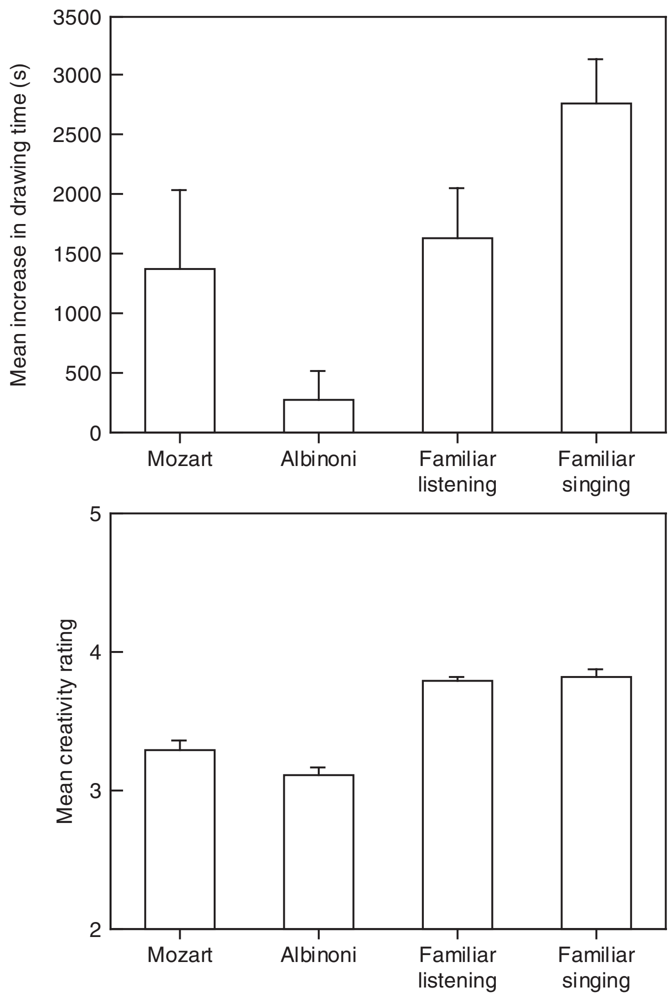

Figure 6.6 Results from experiment 2, Schellenberg *et al.* (in press), illustrating that 5-year-olds' drawing times (upper panel) were longer (compared with baseline) after exposure to familiar music (listening or singing) than to classical music (Mozart or Albinoni). In addition, adults' ratings of creativity (lower panel) were higher for drawings from the children who drew after exposure to familiar music than for those who drew after listening to classical music. Error bars are standard errors.

Music lessons

I now examine whether music *lessons* affect cognitive abilities. Before I begin, it is important to highlight a few critical issues. Our personal experiences can change us—how we think or feel, what we believe to be true, how we look at things (works of art, legal contracts), and so on. It should come as no surprise, then, that taking music lessons not only improves our music-performance abilities, but also our music-listening skills (Dowling & Harwood, 1986; Smith, 1997). These perceptual and cognitive improvements include better recognition of melodies (e.g., Dowling, 1978; Bartlett & Dowling, 1980; Orsmond & Miller, 1999) and a greater likelihood of hearing music in line with predictions from music theory (e.g., understanding that *doh* is more stable than *ti* in a musical context; Krumhansl, 1990). Musical training also leads to differential brain-activation patterns in response to musical stimuli (e.g., Fujioka *et al.*, 2004). Although musical skills are obviously useful for musicians, the benefits are more or less logical outcomes of taking music lessons and playing music. In other words, if we want to say something interesting and provocative about positive benefits of music lessons, we need to show that taking music lessons improves abilities in one or more *non-musical* domains.

A second point involves the *specificity* of observed links between music lessons and cognitive abilities. Music lovers might like to be able to claim that taking music lessons makes you smarter in one way or another. If the claim is to have any real meaning, it is important to show that music is special or unique in this regard. Reading, chess, ballet, and swimming lessons could all confer similar benefits. The claim would then be misleading because it would be far more specific than required. It would be more accurate to say that out-of-school activities *in general* have cognitive benefits.

A third point is that taking music lessons is associated with other demographic variables that are known to be predictive of cognitive advantages. For example, children who take music lessons tend to come from families with higher incomes than average families, and their parents tend to have more education than the average parent (Sergeant & Thatcher, 1974; Curtis, 2004; Schellenberg, in press). To make matters even more complicated, family income and education are both associated positively with measures of cognitive abilities, including IQ scores (e.g., Ceci & Williams, 1997). These associations make it difficult to make definitive conclusions about observed associations between music lessons and cognitive functioning, because family income and parents' education could be the real source of the effect. In short, when one is comparing children with different amounts of musical training, one is— *at the same time*—comparing children from different family backgrounds. Before we can attribute any observed associations to music lessons, contributions from these extraneous factors need to be ruled out in some way. One possibility is to recruit children from families who are equivalent or similar in terms of their background. Another possibility is to partial out the effects of variables such as family income and parents' education by statistical means. These statistical methods adjust the results so that it is *as if* one were testing children from similar family backgrounds.

But even after accounting for potential confounding variables, the presence of positive associations between music lessons and cognitive abilities does not allow researchers to conclude that music lessons are actually *causing* increases in intelligence. In fact, the direction of causation could be in the opposite direction: children with better cognitive abilities might be more inclined than other children to take music lessons. All *correlational studies* and *quasi-experiments* suffer from this limitation. Whereas correlational studies examine whether two or more variables (e.g., duration of musical training and intellectual abilities) increase or decrease in tandem, quasi-experiments compare children that are categorized into groups based on their pre-existing characteristics (e.g., no music lessons vs. some training). Either way, because the children are not assigned at random to music lessons, no inferences about causation can be made.

The only way to infer causation is to conduct a true experiment with random assignment of children to music lessons. The random assignment assures that it is extremely unlikely that extraneous variables (e.g., family income, parents' education, involvement in non-musical activities) would differ between conditions. Even then, the extent of the inferences is limited by the particular comparison conditions. For example, one could recruit a sample of children and assign half of them randomly to music lessons, with the other half receiving no lessons. After a year or two of lessons, the music group might have higher scores on one or more tests of intellectual abilities. One could then infer appropriately that music lessons were indeed the source of the difference between groups. Unfortunately, it would remain unclear whether the *music* part of the lessons played a central role. As noted, a possible alternative is that other types of extracurricular activities could have similar effects. In other words, because the comparison group received no additional lessons of any kind, one cannot rule out the possibility that non-musical aspects of the lessons (e.g., additional contact with an adult instructor) were the source of the effect, and that similar effects would be evident for other out-of-school activities.

In light of these rather far-reaching problems, let us turn to the available research. What do we know about non-musical side-effects of music lessons? As a first pass, we might ask whether musical abilities tend to be correlated with other abilities, or, alternatively, whether they are in a league of their own. Gardner's (1993) theory of *multiple intelligences* implies that musical abilities (i.e., which he calls musical *intelligence*) are distinct and independent from other abilities (or other intelligences). Accordingly, if the human mind is truly *modular* (Fodor, 1983), with autonomous and independent mechanisms handling specific types of input (i.e., linguistic, musical, spatial, and so on), improvements in musical abilities are unlikely to be accompanied by improvements in non-musical domains.

When researchers have examined whether musical *aptitude* (natural musical ability) is associated with other cognitive skills, participants are typically selected without regard to musical training and administered two or more tests. At least one of the tests measures musical abilities and at least one other test measures a non-musical ability. Because the goal is to measure aptitude rather than explicit knowledge of music, musical abilities are often measured by asking participants to identify whether two musical patterns have the same melody or rhythm. Performance on these types of task tends to be correlated positively with general intelligence (Lynn *et al.*, 1989), as well as with more specific components of intelligence such as verbal abilities (Barwick *et al.*, 1989; Lamb & Gregory, 1993; Douglas & Willatts, 1994; Anvari *et al.*, 2002), symbolic reasoning (Gromko & Poorman, 1998a), spatial abilities (Hassler *et al.*, 1985), and reasoning by analogy (Nelson & Barresi, 1989). Because musical aptitude is associated with a variety of other abilities including general intelligence, the simplest explanation of these findings is that more intelligent children perform better on a variety of tests. Another possibility is that improving musical aptitude through musical training could be accompanied by *general* cognitive improvements.

Some researchers believe, however, that taking music lessons is associated with benefits in *specific* non-musical abilities. For example, Rauscher (1999, 2002) proposes that taking music lessons leads to long-term improvements in spatial-temporal abilities, in exactly the same way that listening to music leads to short-term benefits. Another school of thought holds that non-musical benefits of music lessons are primarily linguistic (Chan *et al.*, 1998; Ho *et al.*, 2003), possibly as a consequence of improvements in auditory temporal processing (Jakobson *et al.*, 2003). Yet another view suggests that musical and mathematical abilities are linked closely. This view is a common piece of folk wisdom, and supporters of the spatial-temporal hypothesis also believe that spatial-temporal abilities are linked with mathematical abilities (Rauscher, 1999, 2002; Shaw, 2000). These different theoretical viewpoints lead researchers to use specific types of tests in their investigations (e.g., tests of spatial-temporal *or* linguistic abilities, but not both). But evidence of an association with music lessons in one domain (e.g., spatial-temporal abilities) does not rule out the possibility that a similar association could be evident in another domain (e.g., linguistic abilities).

When considered as a whole, the available correlational and quasi-experimental studies provide evidence that is consistent with the *general* hypothesis (i.e., music lessons affect intellectual abilities generally). They are also consistent with the possibility that children with high IQs—who do well on many outcome measures—are more likely than other children to take music lessons. For example, a relatively recent review (Hetland, 2000a) concluded that taking music lessons is predictive of improved spatial-temporal abilities. Another review (Butzlaff, 2000) reported that taking music lessons is associated positively with reading ability. Yet another review (Vaughn, 2000) found that taking music lessons is predictive of enhanced mathematical skills. Other positive associations have been identified between taking music lessons and a variety of outcome measures, including tests of visual-motor integration (Orsmond & Miller, 1999), selective attention (Hurwitz *et al.*, 1975), and memory for verbal stimuli (Chan *et al.*, 1998; Kilgour *et al.*, 2000; Ho *et al.*, 2003; Jakobson *et al.*, 2003). In sum, the available data from correlational and quasi-experimental studies point to small but reliable associations between music lessons and intellectual abilities in general, without informing us about the direction of the association.

Are smarter children more likely than other children to take music lessons? Or do music lessons improve intellectual abilities? Or could both of these hypotheses be true? Let us turn now to the experimental studies that have examined whether music lessons affect cognitive abilities. In one such study (Rauscher & Zupan, 2000), kindergarten children were assigned to one of two conditions. In one condition, the children served as a control group (no music lessons). In the other condition, children received 20-minute keyboard lessons twice a week for 8 months. The children were administered a set of three spatial tasks (two spatial-temporal, one spatial memory) before the lessons began (pre-test) and after they were completed (post-test). Compared with the no-music group, the keyboard group had significantly higher increases from pre- to post-test on all three spatial measures. These effects disappeared a year later for children who stopped taking lessons, but they continued to increase for children who continued taking music lessons (Rauscher, 2002). In fact, children who took lessons continuously from kindergarten through third grade proved to have better spatial skills than children who started lessons in second grade. These results suggest that musical training, particularly training that begins early in life, is associated with benefits in spatial abilities (see also Gromko & Poorman, 1998b). Unfortunately, it is unclear whether similar benefits would be found for verbal or mathematical abilities, or for general intelligence. It is also unclear whether other types of training (in drama, gymnastics, etc.) would have similar benefits.

In another experimental study (Costa-Giomi, 1999), 9-year-old children received 3 years of weekly individual piano lessons, or no lessons. Children were administered a short test of cognitive abilities that provided an overall score as well as separate subscores for verbal, quantitative, and spatial abilities. The test was administered at the beginning of the study and each year thereafter. The groups did not differ at the beginning or at the end of the study, but the results revealed small but temporary advantages for the music group on the overall score after the second year, and on the spatial subtest after the first and second years. Studying children who begin music lessons at an earlier age might yield results that are stronger, more interpretable, and less temporary.

Rather provocative findings came from a study that provided four first-grade classes with a 7-month programme in the arts that included specialized training in music and visual arts (Gardiner *et al.*, 1996). The music lessons were taught in the Kodály method, which emphasizes clapping, hand signs, dancing, and singing. The four special-arts classes were compared with four others who received the standard curriculum. Although the children in the special-arts classes were behind the other classes before the study began, after the programme was finished they matched the other classes in reading ability and surpassed them in mathematics. These results are particularly exciting because the outcome measures included real-world outcomes (i.e., measures of academic achievement) rather than abstract measures of intelligence or its subcomponents. None the less, it is impossible to attribute the positive outcomes to the music lessons rather than the visual component of the special-arts programme. Moreover, even if the results were a consequence of the music curriculum, it would remain unclear whether they were due to music rather than to one or more features of the particular teaching method.

In a recent field experiment (Schellenberg, 2004), I tried to rectify some of the problems that precluded clear interpretations of the earlier findings (Gardiner *et al.*, 1996; Gromko & Poorman, 1998b; Costa-Giomi, 1999; Rauscher & Zupan, 2000). Families of 6-year-old children were recruited by placing an ad in a local newspaper, offering 'free arts lessons'. Parents were then interviewed on the telephone and at their homes to ensure that: (1) they were interested in participating regardless of the condition to which their child was assigned; (2) they had a keyboard in their home with at least four octaves of full-size keys; (3) their child was registered in public school; and (4) their child had never taken music lessons previously. A group of 144 families was selected based on these criteria. Unlike previous studies, the children were assigned individually and at random to one of four groups: keyboard lessons, voice (Kodály) lessons, drama lessons, or no lessons. The lessons were weekly lessons taught in groups of six for 36 weeks. (The no-lessons group received keyboard lessons the following year.) All of the lessons were taught at the Royal Conservatory of Music, which is the oldest and most prestigious institution of its type in Canada. The instructors were certified female professionals who taught music or drama professionally on a regular basis. The drama lessons provided a control condition (in addition to the no-lessons group) that, like music, was an arts activity that had a primary auditory component and incorporated memorization, practice, and rehearsal.

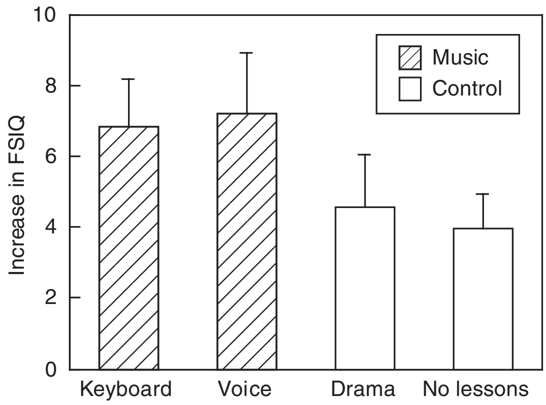

Figure 6.7 Results from Schellenberg (2004), illustrating that children who took music lessons (keyboard or voice) had larger increases in FSIQ than children who took drama lessons or no lessons. Error bars are standard errors.

Each child was tested once before the lessons began (before entering first grade) and again after the lessons were over (in the summer between first and second grades). Twelve of the 108 children in the keyboard, voice, and drama groups stopped going to the lessons mid-way through the year and were not available for the second testing session. The outcome measures included the entire Wechsler Intelligence Scale for Children—Third Edition (WISC-III; Wechsler, 1991), which has 12 subtests that measure a wide variety of skills. The subtests are combined to give a full-scale IQ score (FSIQ), as well as four index scores (Verbal Comprehension, Perceptual Organization, Processing Speed, and Freedom from Distractibility), that correspond to the *principal components* (i.e., independent dimensions) of the test. The children were also administered the Kaufman Test of Educational Achievement (K-TEA; Kaufman & Kaufman, 1985), which is a standardized test of academic ability that includes five subtests of specific mathematical and reading abilities. A parent completed the Behavioural Assessment System for Children—parent report form (BASC; Reynolds & Kamphaus, 1992), which provides measures of adaptive and maladaptive social behaviour. The K-TEA was included to test whether any potential differences in WISC-III scores would translate to applied differences in scholastic ability. The BASC was included to test whether potential side-effects of music lessons would extend beyond cognitive abilities to social behaviour.

Across the four groups, the children had reliable increases in FSIQ from the pre-test to the post-test session that averaged 5.7 points. This finding is likely to be a consequence of attending school, which is known to raise IQ (Ceci & Williams, 1997). When these increases were analysed as a function of the various conditions, the two music groups (keyboard and voice) had similar increases in FSIQ, as did the two control groups (drama and no-lessons). When the music groups were compared with the control groups, however, a reliable difference was found (see Figure 6.7). The control groups had increases in FSIQ that averaged 4.3 points, whereas the music groups had an average increase of 7.0 points. Because the experiment included random assignment of children to the four groups, the

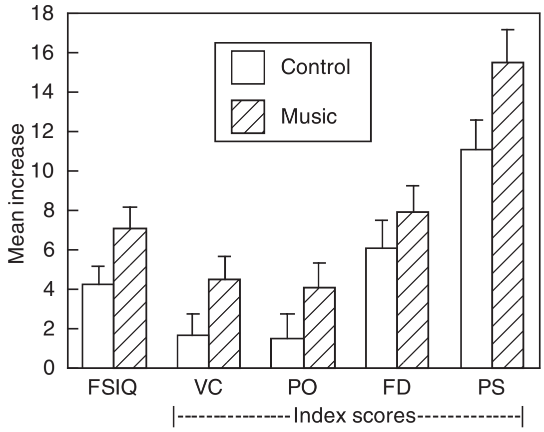

Figure 6.8 Results from Schellenberg (2004), illustrating that the advantage for the music groups (keyboard or voice lessons) over the control groups (drama or no lessons) was consistent across the four index scores of the WISC-III (VC: Verbal Comprehension, PO: Perceptual Organization, FD: Freedom from Distractibility, PS: Processing Speed) as well as full-scale IQ (FSIQ).

results allow one to infer causation, namely that taking music lessons led to greater increases in FSIQ than taking drama lessons or no lessons at all.

The findings refute suggestions of links between music education and specific aspects of cognition. Compared with the control groups, the music groups had greater increases on all four index scores of the WISC-III (see Figure 6.8), and on 10 of its 12 subtests—all but Arithmetic and Information. The Arithmetic subtest requires children to do basic mental addition, subtraction, multiplication, and division in response to real-world questions, whereas Information is a test of verbal abilities that measures participants' knowledge of common events, objects, places, and people. Because the *control* groups actually had larger improvements (not significantly) on these two subtests, the findings provide rather compelling evidence that musical training does *not* lead to special improvements in mathematical or verbal abilities. Moreover, other subtests that measured spatial-temporal abilities (Object Assembly), verbal abilities (Vocabulary), or processing speed (Symbol Search, Coding) did not stand out in terms of the improvements that could be attributed to music lessons. In fact, improvements on these tests was no different in magnitude than the improvement noted on subtests of working memory (Digit Span), understanding similarities between concepts (Similarities), and so on.

Having shown that taking music lessons causes small but significant increases in FSIQ, one might ask whether these benefits have any applied relevance that extends to performance in traditional school subjects. When the music and control groups were compared on the five subtests of the K-TEA, they did not differ significantly in any case. None the less, the music group had larger improvements on each of the five subtests. If the null hypothesis of 'no difference between groups' were actually true in each case, it should be like flipping a coin five times in a row. The odds of *heads* coming up (or the music group having a larger increase) each time is 1 in 32, which is less than 0.05 and therefore statistically significant by the rules of science.

A separate analysis asked whether side-effects of music lessons would be limited to intellectual abilities (e.g., IQ, academic performance) or whether they might also improve social skills. Results from the BASC revealed that levels of maladaptive behaviour were very low across groups and did not change over the year of the study. This null finding was to be expected because the items measuring maladaptive behaviour are designed to identify at-risk children who require clinical intervention. On the measure of *adaptive* social skills, however, the drama group showed a significant improvement over the course of the study. This improvement was not evident for any of the other groups, and the difference between the drama and other groups was highly significant. Although this finding was not predicted in advance, it seems sensible in hindsight. The interactive and essentially social nature of drama lessons appears to improve adaptive social skills, such as cooperating with peers, and behaving politely and appropriately in interactions with adults and other children.

These findings represent the first clear pieces of evidence that taking music lessons *causes* positive intellectual benefits. It is important to keep in mind that the benefits were relatively small (slightly less than 3 points). Moreover, when the findings are considered as a whole, they suggest that extracurricular activities *in general* may be beneficial for child development, with different activities (e.g., music or drama) conferring benefits in different areas (e.g., intellectual or social skills, respectively). The results also raise an important question: Would the benefits of music lessons continue to grow with additional lessons? Unfortunately, this question is almost impossible to answer using a true experiment. In the Schellenberg (2004) study, one of every nine children in the music and drama groups dropped out of the study before it was completed. Although this rate of attrition was considered to be acceptable, higher rates would make the experiment invalid because children who drop out are likely to differ systematically from children who persevere (e.g., in terms of motivation, ability to concentrate, and so on). This problem becomes especially troublesome when rates of attrition differ for the different groups.

As an alternative, we can address the issue with a correlational design, by looking at children with different amounts of music lessons to determine whether intellectual abilities tend to increase with amount of training. Strictly speaking, this approach means that causation cannot be determined. In principle, positive results could mean that (1) music lessons cause intellectual benefits, (2) intellectually gifted children are more likely than other children to take music lessons, or (3) some other variable is causing increases in the likelihood of taking music lessons and scoring well on measures of intellectual abilities. Obvious candidates for these other variables include parents' education, family income, and involvement in non-musical out-of-school activities. Fortunately, these variables can be measured relatively accurately—and held constant in the statistical analyses—simply by asking parents to provide the relevant information. In short, the correlational approach allows us to test whether the most likely extraneous variables are the true source of any observed effects. If these can be ruled out, the results from the earlier experimental study provide evidence about the direction of causation.

In the first of two correlational studies (Schellenberg, in press), 147 children were recruited from the local area. The families ranged from lower-middle to upper-middle

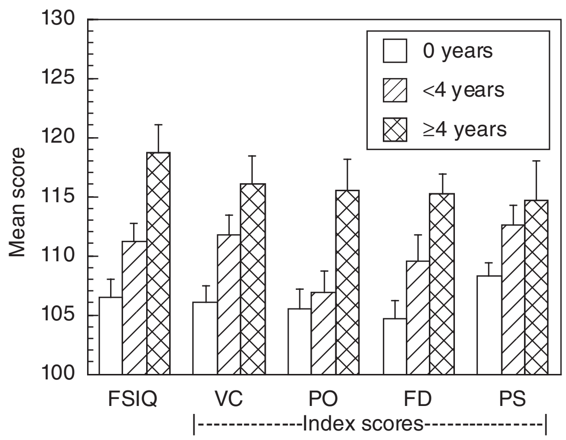

Figure 6.9 Results from Schellenberg (in press), illustrating full-scale IQ (FSIQ) and WISC-III index scores (VC: Verbal Comprehension, PO: Perceptual Organization, FD: Freedom from Distractibility, PS: Processing Speed) for children 6–12 years of age as a function of years of music lessons. Error bars are standard errors.

class in terms of social status (i.e., family income and parents' education), and they were very mixed with respect to ethnic background. The children came to the laboratory with a parent on a single occasion. Each child was administered the complete WISC-III and the K-TEA. A parent completed the BASC as well as a detailed questionnaire asking for background information about the child's history of music lessons, the child's involvement in non-musical out-of-school activities, the parents' highest level of education, and total family income. In addition, parents were asked to provide a photocopy of the child's most recent report card. (Report cards are standardized across publicly funded schools in the province of Ontario and thus comparable.) For each child, we used the grades on the report card to calculate an average grade in school.

The main predictor variable was the total number of months of private and group music lessons taken outside of school. As predicted, this variable was correlated positively with FSIQ ($r = 0.35$; see Figure 6.9). The association was smaller but still reliable after holding constant individual differences in family income, parents' education, involvement in non-musical activities, and age. (Age was included because for any individual child, age always increases with total months of music lessons.) In general, parents' education was a better predictor than music lessons of performance on the WISC-III measures, but musical training was a better predictor than family income. Involvement in non-musical activities was not associated with WISC-III scores. The association between music lessons and the various WISC-III outcome measures was strongest for FSIQ, but it was statistically significant for each index score and for all but one of the 12 individual subtests. The exception was Object Assembly, the only WISC-III subtest that measures spatial-temporal abilities. Once again, the results provide evidence against all of the theories that link music lessons with specific subsets of intellectual functioning. Instead, they point to a small but very *general* association. Moreover, there was no evidence that non-musical out-of-school activities have similar intellectual benefits.

When music lessons were used to predict school average and performance on the standardized test of academic abilities (K-TEA), a similar pattern emerged. Both of these outcome measures had a reliable positive association with music lessons, and the associations remained reliable (albeit smaller) after accounting for individual differences in parental education, family income, non-musical activities, and age. As in the experimental study (Schellenberg, 2004), music lessons had no association with adaptive or maladaptive social functioning. In sum, the results from this correlational study were completely consistent with those from the experiment, and they provided the first evidence that, on average, the intellectual benefits caused by music lessons increase as duration of musical training increases. Obviously, other differences among children in motivation, peer groups, social status, number of siblings, and so on, are likely to play a part in determining both how long a child takes music lessons and how much intellectual benefit is accrued.

A second correlational study of 150 undergraduates (Schellenberg, in press) tested whether taking music lessons in childhood and adolescence confers intellectual benefits that last until early adulthood. The students came individually to the laboratory and were administered the entire Wechsler Adult Intelligence Scale—Third Edition (WAIS-III; Wechsler, 1997), which is similar to the WISC-III but designed for testing adults rather than children. The students also provided detailed information about their musical background, which included years of private music lessons (group lessons outside of school were rare) as well as years of playing music on a regular basis. The latter measure was included to account for the likelihood that effects of musical training would differ, for example, between one student who took music lessons for 3 years but never played a note afterward, and another student who also took music lessons for 3 years but continued to play regularly for an additional 4 years. Accordingly, the main predictor variable was years of playing music regularly (i.e., years of private lessons plus additional years of regular playing). The students also provided information about their high-school average, their parents' highest level of education, and their family income.

Years of playing music regularly had a reliable positive association with FSIQ ($r = 0.21$; see Figure 6.10). The effect was smaller than it was in childhood, probably because more time had elapsed since the musical training ended. The association remained reliable after accounting for parents' education and family income. Examination of the WAIS-III index and subtest scores revealed significant associations for some outcome measures but not for others. None the less, the results were not consistent with any proposals of links between music lessons and specific subsets of intellectual abilities. Moreover, playing music lessons had the strongest predictive power for FSIQ, which is an aggregate measure that is formed from *all* of the subtests. Playing music also had a small but reliable positive association with high-school average that could not be attributed to family income or parents' education. These results suggest that associations between music lessons and intellectual abilities are small but very general and long-lasting, continuing some years after the lessons have ended.

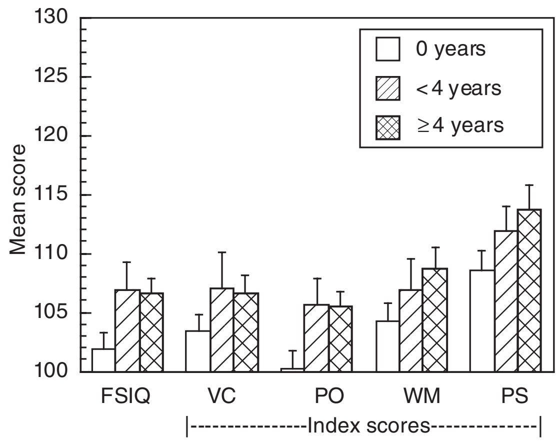

Figure 6.10 Results from Schellenberg (in press), illustrating full-scale IQ (FSIQ) and WAIS-III index scores (VC: Verbal Comprehension, PO: Perceptual Organization, WM: Working Memory, PS: Processing Speed) for undergraduates as a function of years of playing music regularly. Error bars are standard errors.

Conclusions

On the one hand, studies of music listening show that the Mozart effect is relatively reliable. On the other hand, the results also make it clear that the effect is not specific to music composed by Mozart in particular, or even to music in general. Moreover, the effects go well beyond tests of spatial-temporal abilities to other components of intelligence, such as creativity or recognizing patterns rapidly. Is it fair, then, to say that listening to music confers intellectual benefits? Yes, but it is misleading to suggest that music is somehow special in this regard. Specific characteristics of music (e.g., tempo or mode) can induce changes in listeners' arousal levels and their moods, but so can drinking a cup of coffee, or receiving a gift of $5. As noted above, it is well established that changes in arousal affect performance on tests of cognitive abilities, as do changes in mood. In other words, there are many simple but temporary and small fixes to the problem of intelligence.

Studies of formal training in music tell a different but related story. The available findings reveal small but reliable and consistent associations between taking music lessons and intellectual abilities. The association appears to be causal and cannot be attributed to extraneous variables that are associated with taking music lessons or cognitive abilities. The available evidence also indicates that associations between music lessons and cognitive abilities are general—extending broadly across the various subcomponents of intelligence and cognition—rather than limited to a specific subset of abilities. Other out-of-school activities (e.g., drama lessons) do not appear to have similar intellectual benefits, although they may have benefits for other aspects of child development (e.g., social skills).

If the effects of music listening are due to changes in arousal and mood, can we explain the effects of learning to play music with similar underlying mechanisms? Despite some speculation that this is indeed possible (Rauscher, 1999, 2002), the answer *must* be 'no' for at least two reasons: (1) taking music lessons and practising regularly over a period of time could not conceivably have the same emotional impact day in and day out, and (2) in studies of effects of music training, the outcome variables are *never* measured directly after listening to music.

How, then, can we explain the effect? There are at least three distinct possibilities. One is that the effect is simply an extension of the well-known fact that schooling raises IQ (Ceci & Williams, 1997). From this perspective, other out-of-school activities that are scholastic in nature (e.g., reading, maths, or chess lessons) could have similar effects. Music lessons could still be unique because, unlike reading, maths, or chess lessons, they represent a scholarly out-of-school activity that many children *enjoy*. Another possibility is that the intellectual benefits of music lessons stem from one or more of the wide array of abilities that are trained and improved when learning to play music. These include fine-motor skills, learning to read music, learning to perceive and express emotions in music, memorization of extended passages, acquired knowledge of musical structures (e.g., scales, chords, intervals, cadences and other harmonic progressions), and so on. Most of these factors (memorizing, reading, fine-motor skills, perceiving/expressing emotion) are *not* specific to music. Thus, it is possible that a non-musical activity that incorporated some or all of these factors could confer similar benefits. A third possibility is that something specific about music is driving the effect. A musical tune is an *abstraction*, which means that it can be recognized whether it is played fast or slow, or high or low. In other words, a tune is defined by the pitch and temporal relations that establish its identity. Learning explicitly about the abstract nature of music could lead to an improved ability to reason abstractly in general, which would, in turn, explain the observed increases on measures of intellectual ability. Yet another possibility is that learning to play music is similar to learning a second language. Bilingualism is known to confer some non-linguistic cognitive advantages (Bialystok, 2001).

Although the source of the effect of music *listening* on intellectual abilities has been identified (at least to my satisfaction), the source of the effect of music *lessons* remains more elusive. I have offered some ideas to explain the effect but researchers will undoubtedly continue to examine this question in more detail in the future. None the less, I think that it is safe to conclude at this point that a reasonable amount of out-of-school activities is good for child development. Music lessons represent one option that appears to confer small but general intellectual benefits. When considered in conjunction with the cost and effort required to master a musical instrument, it is clear that music lessons are *not* a simple fix to a complex problem, or an easy way to raise intelligence. Deciding which activity is most appropriate for a particular child depends on many factors, primarily the child's interests and abilities, what the family can afford, and what can fit into the busy schedules of modern lives.

Acknowledgements

Preparation of this chapter was supported by the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada. Correspondence should be sent to Glenn Schellenberg, Department of

Psychology, University of Toronto at Mississauga, Mississauga, ON, Canada L5L 1C6 (e-mail: g.schellenberg@utoronto.ca).

References

Anvari, S. H., Trainor, B. J., Woodside, J., & Levy, B.A. (2002). Relations among musical skills, phonological processing and early reading abilities in pre-school children. *Journal of Experimental Child Psychology*, **83**, 111–130.

Bartlett, J. C. & Dowling, W. J. (1980). Recognition of transposed melodies: A key-distance effect in developmental perspective. *Journal of Experimental Psychology: Human Perception and Performance*, **6**, 501–515.

Barwick, J., Valentine, E., West, R., & Wilding, J. (1989). Relations between reading and musical abilities. *British Journal of Educational Psychology*, **59**, 253–257.

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition.* New York: Cambridge University Press.

Brody, N. (1997). Intelligence, schooling, and society. *American Psychologist*, **52**, 1046–1050.

Butzlaff, R. (2000). Can music be used to teach reading? *Journal of Aesthetic Education*, **34**(3/4), 167–178.

Cahill, L. & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neurosciences*, **21**, 294–299.

Carstens, C. B., Huskins, E., & Hounshell, G. W. (1995). Listening to Mozart may not enhance performance on the revised Minnesota Paper Form Board Test. *Psychological Reports*, **77**, 111–114.

Cassady, J. C. & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology*, **27**, 270–295.

Ceci, S. J. & Williams, W. M. (1997). Schooling, intelligence and income. *American Psychologist*, **52**, 1051–1058.

Chabris, C. F. (1999). Prelude or requiem for the 'Mozart Effect'? *Nature*, **400**, 826–827.

Chan, A. S., Ho., Y.-C., & Cheung, M.-C. (1998). Music training improves verbal memory. *Nature*, **396**, 128.

Costa-Giomi, E. (1999). The effects of three years of piano instruction on children's cognitive development. *Journal of Research in Music Education*, **47**, 198–212.

Curtis, P. (2004, October 22). Music lessons 'dominated by middle-class girls'. *The Guardian.*

Deary, I. J., Whiteman, M. C., Starr, J. M., Whalley, L. J., & Fox, H. C. (2004). The impact of childhood intelligence on later life: Following up the Scottish Mental Surveys of 1932 and 1947. *Journal of Personality and Social Psychology*, **86**, 130–147.

Douglas, S. & Willatts, P. (1994). The relationship between musical ability and literacy skills. *Journal of Research and Reading*, **17**, 99–107.

Dowling, W. J. (1978). Scale and contour: Two components of a theory of memory for melodies. *Psychological Review*, **85**, 341–354.

Dowling, W. J. & Harwood, D. L. (1986). *Music cognition.* Orlando, FL: Academic Press.

Dutton, A. & Carroll, M. (2001). Eyewitness testimony: Effects of source of arousal on memory, source-monitoring, and metamemory judgments. *Australian Journal of Psychology*, **53**, 83–91.

Eich, E. & Forgas, J. P. (2003). Mood, cognition, and memory. In A. F. Healy & R. W. Proctor (eds), *Handbook of psychology: Experimental psychology*: *Vol.* **4**. (pp. 61–83). New York: Wiley.

Fodor, J. A. (1983). *The modularity of mind.* Cambridge, MA: Bradford.

Fujioka, T., Trainor, L. J., Ross, B., Kakigi, R., & Pantev, C. (2004). Musical training enhances automatic encoding of melodic contour and interval structure. *Journal of Cognitive Neuroscience*, **16**, 1010–1021.

Gabrielsson, A. (2001). Emotions in strong experiences with music. In P. N. Juslin & J. A. Sloboda (eds), *Music and emotion: Theory and research* (pp. 431–449). New York: Oxford University Press.

Gardiner, M. F., Fox, A., Knowles, F., & Jeffrey, D. (1996). Learning improved by arts training. *Nature*, **381**, 284.

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences* (2nd edn). New York: Basic Books.

Gottfredson, L.S. (1997). Why *g* matters: The complexity of everyday life. *Intelligence*, **24**, 79–132.

Gottfredson, L. S. & Deary, I. J. (2004). Intelligence predicts health and longevity, but why? *Current Directions in Psychological Science*, **13**, 1– 4.

Grawitch, M. J., Munz, D. C., Elliott, E. K., & Mathis, A. (2003). Promoting creativity in temporary problem-solving groups: The effects of positive mood and autonomy in problem definition on idea-generating performance. *Group Dynamics*, **7**, 200–213.

Gromko, J. E. & Poorman, A. S. (1998a). Developmental trends and relationships in children's aural perception and symbol use. *Journal of Research in Music Education*, **46**, 16–23.

Gromko, J. E. & Poorman, A. S. (1998b). The effect of music training on preschoolers' spatial-temporal task performance. *Journal of Research in Music Education*, **46**, 173–181.

Hassler, M., Birbaumer, N., & Feil, A. (1985). Musical talent and visual spatial-ability: A longitudinal study. *Psychology of Music*, **13**, 99–113.

Hetland, L. (2000a). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education*, **34**(3/4), 179–238.

Hetland, L. (2000b). Listening to music enhances spatial-temporal reasoning: Evidence for the 'Mozart effect'. *Journal of Aesthetic Education*, **34**(3/4), 105–148.

Ho, Y.-C., Cheung, M.-C., & Chan, A. S. (2003). Music training improves verbal but not visual memory: Cross sectional and longitudinal explorations in children. *Neuropsychology*, **17**, 439–450.

Hurwitz, I., Wolff, P. H., Bortnick, B. D., & Kokas, K. (1975). Nonmusical effects of the Kodály music curriculum in primary grade children. *Journal of Learning Disabilities*, **8**, 167–174.

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of musical tempo and mode on arousal, mood, and spatial abilities. *Music Perception*, **20**, 151–171.

Isen, A. M., Niedenthal, P., & Cantor, N. (1992). An influence of positive affect on social categorization. *Motivation and Emotion*, **16**, 65–78.

Jakobson, L. S., Cuddy, L. L., & Kilgour, A. R. (2003). Time tagging: A key to musicians' superior memory. *Music Perception*, **20**, 307–313.

Kaufman, A. S. & Kaufman, N. L. (1985). *Kaufman Test of Educational Achievement.* Circle Pines, MN: American Guidance Service.

Khan, B. E. & Isen, A. M. (1993). The influence of positive affect on variety-seeking among safe, enjoyable products. *Journal of Consumer Research*, **20**, 257–270.

Kilgour, A. R., Jakobson, L. S., & Cuddy, L. L. (2000). Music training and rate of presentation as mediators of text and song recall. *Memory & Cognition*, **28**, 700–710.

Krumhansl, C. L. (1990). *Cognitive foundations of musical pitch.* New York: Oxford University Press.

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology*, **51**, 336–352.

Lamb, S. J. & Gregory, A. H. (1993). The relationship between music and reading in beginning readers. *Educational Psychology*, **13**, 19–27.

Lynn, R., Wilson, R. G., & Gault, A. (1989). Simple musical tests as measures of Spearman's g. *Personality and Individual Differences*, **10**, 25–28.

Nantais, K. M. & Schellenberg, E. G. (1999). The Mozart effect: An artifact of preference. *Psychological Science*, **10**, 370–373.

Nelson, D. J. & Barresi, A. L. (1989). Children's age-related intellectual strategies for dealing with musical and spatial analogical tasks. *Journal of Research in Music Education*, **37**, 93–103.

Newman, J., Rosenbach, J. H., Burns, K. L., & Latimer, B. C. (1995). An experimental test of the 'Mozart Effect': Does listening to his music improve spatial ability? *Perceptual and Motor Skills*, **81**, 1379–1387.

Orsmond, G. I. & Miller, L. K. (1999). Cognitive, musical and environmental correlates of early music instruction. *Psychology of Music*, **27**, 18–37.

Peretz, I. (2001). Listen to the brain: A biological perspective on musical emotions. In P. N. Juslin & J. A. Sloboda (eds), *Music and emotion: Theory and research* (pp. 105–134). New York: Oxford University Press.

Rauscher, F. H. (1999). Prelude or requiem for the 'Mozart effect'? *Nature*, **400**, 827–828.

Rauscher, F. H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 267–278). San Diego: Academic Press.

Rauscher, F. H. & Shaw, G. L. (1998). Key components of the Mozart effect. *Perceptual and Motor Skills*, **86**, 835–841.

Rauscher, F. H. & Zupan, M. A. (2000). Classroom keyboard instructions improve kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly*, **15**, 215–228.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, **365**, 611.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1995). Listening to Mozart enhances spatial-temporal reasoning: Towards a neurophysiological basis. *Neuroscience Letters*, **185**, 44–47.

Reynolds, C. R. & Kamphaus, R. W. (1992). *Behavior assessment system for children*. Circle Pines, MN: American Guidance Service.

Rideout, B. E. & Laubach, C. M. (1996). EEG correlates of enhanced spatial performance following exposure to music. *Perceptual and Motor Skills*, **82**, 427–432.

Rideout, B. E. & Taylor, J. (1997). Enhanced spatial performance following 10 minutes exposure to music: A replication. *Perceptual and Motor Skills*, **85**, 112–114.

Rideout, B. E., Dougherty, S., & Wernert, L. (1998). Effect of music on spatial performance: A test of generality. *Perceptual and Motor Skills*, **86**, 512–514.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, **39**, 1161–1178.

Schellenberg, E. G. (2001). Music and non-musical abilities. *Annals of the New York Academy of Sciences*, **930**, 355–371.

Schellenberg, E. G. (2003). Does exposure to music have beneficial side effects? In I. Peretz & R. J. Zatorre (eds), *The cognitive neuroscience of music* (pp. 430–448). Oxford: Oxford University Press.

Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychological Science*, **15**, 511–514.

Schellenberg, E. G. (in press). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology*.

Schellenberg, E. G. & Hallam, S. (2005). Music listening and cognitive abilities in 10- and 11-year-olds: The Blur effect. *Annals of the New York Academy of Science*, **1060**, 202–209.

Schellenberg, E. G., Nakata, T., Hunter, P. G., & Tamoto, S. (in press). Exposure to music and cognitive performance: Tests of children and adults. *Psychology of Music*.

Schmidt, L. A. & Trainor, L. J. (2001). Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical emotions. *Cognition and Emotion*, **15**, 487–500.

Sergeant, D. & Thatcher, G. (1974). Intelligence, social status, and musical abilities. *Psychology of Music*, **2**, 32–57.

Shaw, G.L. (2000). *Keeping Mozart in mind*. San Diego: Academic Press.

Sloboda, J. A. (1992). Empirical studies of emotional response to music. In M. R. Jones & S. Holleran (eds), *Cognitive bases of musical communication* (pp. 33–46). Washington, DC: American Psychological Association.

Sloboda, J. A. & Juslin, P. N. (2001). Psychological perspectives on music and emotion. In P. N. Juslin & J. A. Sloboda (eds), *Music and emotion: Theory and research* (pp. 71–104). New York: Oxford University Press.

Smith, J. D. (1997). The place of musical novices in music science. *Music Perception*, **14**, 227–262.

Steele, K. M., Ball, T. M., & Runk, R. (1997). Listening to Mozart does not enhance backwards digit span performance. *Perceptual and Motor Skills*, **84**, 1179–1184.

Steele, K. M., Brown, K. M., & Stoecker, J. A. (1999a). Failure to confirm the Rauscher and Shaw description of recovery of the Mozart effect. *Perceptual and Motor Skills*, **88**, 843–848.

Steele, K. M., Bass, K. E., & Crook, M. D. (1999b). The mystery of the Mozart effect: Failure to replicate. *Psychological Science*, **10**, 366–369.

Steele, K. M., Dalla Bella, S., Peretz, I., Dunlop, T., Dawe, L. A., Humphrey, G. K., Shannon, R. A., Kirby Jr., K. L., & Olmstead, C. G. (1999c). Prelude or requiem for the 'Mozart effect'? *Nature*, **400**, 827.

Sternberg, R. J., Grigorenko, E. L., & Bundy, D. A. (2001). The predictive value of IQ. *Merrill-Palmer Quarterly*, **47**, 1–41.

Stough, C., Kerkin, B., Bates, T., & Mangan, G. (1994). Music and spatial IQ. *Personality and Individual Differences*, **17**, 695.

Thayer, J. F. & Levenson, R. (1983). Effects of music on psychophysiological responses to a stressful film. *Psychomusicology*, **3**, 44–54.

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood and the Mozart effect. *Psychological Science*, **12**, 248–251.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *The Stanford-Binet Intelligence Scale* (4th edn). Chicago: Riverside.

Vaughn, K. (2000). Music and mathematics: Modest support for the oft-claimed relationship. *Journal of Aesthetic Education*, **34(3/4)**, 149–166.

Wechsler, D. (1991). *Wechsler intelligence scale for children* (3rd edn). San Antonio, TX: Psychological Corporation.

Wechsler, D. (1997). *Wechsler adult intelligence scale* (3rd edn). San Antonio, TX: Psychological Corporation.