Exposure to music and cognitive performance: tests of children and adults

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ABSTRACT This article reports on two experiments of exposure to music and cognitive performance. In Experiment 1, Canadian undergraduates performed better on an IQ subtest (Symbol Search) after listening to an up-tempo piece of music composed by Mozart in comparison to a slow piece by Albinoni. The effect was evident, however, only when the two pieces also induced reliable differences in arousal and mood. In Experiment 2, Japanese 5-year-olds drew for longer periods of time after singing or hearing familiar children's songs than after hearing Mozart or Albinoni, and their drawings were judged by adults to be more creative, energetic, and technically proficient. These results indicate that (1) exposure to different types of music can enhance performance on a variety of cognitive tests, (2) these effects are mediated by changes in emotional state, and (3) the effects generalize across cultures and age groups.

KEYWORDS: cognition and emotion, cognitive ability, intellectual ability, Mozart effect, music and cognition, music listening

The impact of music on listeners' emotional state is well documented (e.g. Gabrielsson, 2001; Husain et al., 2002; Krumhansl, 1997; Peretz, 2001; Schmidt and Trainor, 2001; Sloboda and Juslin, 2001; Thayer and Levenson, 1983; Thompson et al., 2001), as is the effect of emotional state on participants' performance on a wide variety of cognitive measures. According to Russell's (1980) circumplex model of emotions, emotions vary in two-dimensional space, with one dimension corresponding to arousal (or activation) and the other to mood (or valence). Arousal refers to degree of physical and psychological activation or to the intensity of the felt emotion, whereas mood indicates whether the emotion is positive or negative. Both arousal (Anderson and Bushman, 2001; Cahill and McGaugh, 1998; Caldwell et al., 2004; Cassady and Johnson, 2002; Dutton and Carroll, 2001;

Husain et al., 2002; Lyvers et al., 2004; Thompson et al., 2001) and mood (Grawitch et al., 2003; Husain et al., 2002; Isen et al., 1992; Khan and Isen, 1993; Thompson et al., 2001; for reviews see Ashby et al., 1999; Eich and Forgas, 2003; Isen, 1999) have robust effects on cognition.

The *arousal and mood hypothesis* (Thompson et al., 2001) proposes that when music listening affects cognitive abilities, such effects can be attributed to changes in listeners' arousal or mood (see also Hallam et al., 2002). Whereas musical tempo seems to be associated primarily with arousal (i.e. faster tempi are more arousing than slower tempi), musical mode is a better predictor of mood (i.e. major and minor modes evoke happiness and sadness, respectively; Husain et al., 2002). Associations linking tempo and arousal to cognition are likely to be more robust than those linking mode and mood to cognition. Tempo varies continuously and infinitely (at least in principle), whereas mode is dichotomous. Effects of tempo on emotional evaluations of music also emerge earlier in development than those of mode (Dalla Bella et al., 2001). Moreover, tempo variations are universal, whereas the major–minor distinction is specific to Western music. As such, listeners can use tempo (but not mode) to decode the emotions conveyed by music from foreign cultures (Balkwill and Thompson, 1999; Balkwill et al., 2004).

The arousal and mood hypothesis provides a framework for understanding and explaining the so-called 'Mozart effect'. The effect refers to enhanced performance on spatial–temporal measures after listening to music composed by Mozart compared to control conditions that involve sitting in silence or listening to relaxation instructions (Rauscher et al., 1993). The authors (Rauscher and Shaw, 1998; Rauscher et al., 1995) explain the effect as a consequence of cross-modal priming between unrelated domains (i.e. music composed by Mozart and spatial–temporal abilities; for a review see Hetland, 2000), a claim that is at odds with the priming and neuropsychological literatures (Schellenberg, 2003). By contrast, the arousal and mood hypothesis posits that the Mozart effect is neither specific to music in general (let alone Mozart in particular), nor to tests that measure spatial–temporal abilities (i.e. those 'involving mental imagery and temporal ordering', Rauscher, 1999: 827).

In line with this perspective, 'Bach' (Ivanov and Geake, 2003), 'Schubert' (Nantais and Schellenberg, 1999), and 'Yanni' (Rideout et al., 1998) 'effects' have also been reported. Moreover, when listening to Mozart is compared with an engaging but nonmusical auditory stimulus (e.g. a narrated story), the effect disappears (Nantais and Schellenberg, 1999). Rather, participants perform better on a cognitive test after listening to their preferred stimulus (Mozart or story). When the comparison condition involves listening to Albinoni's *Adagio* (a slow, minor key piece often played at funerals), the Mozart advantage on a subsequent cognitive test proves to be a consequence of changes in listeners' arousal levels and mood (Thompson et al., 2001). The Mozart sonata used in most experiments (e.g. Husain et al., 2002; Nantais and Schellenberg, 1999; Rauscher et al., 1993, 1995; Steele, Bass et al., 1999; Thompson et al., 2001) is a relatively fast-tempo piece in a major key.

The present investigation provided further tests of the arousal and mood hypothesis and its ability to account for the Mozart effect. In two experiments, we examined whether beneficial side effects of music listening on cognition extend to tests that do *not* measure spatial–temporal abilities. In Experiment 1, Canadian adults completed one of two subtests from the Wechsler Adult Intelligence Scale–Third Edition (WAIS-III, Wechsler, 1997) after listening to the Mozart or Albinoni pieces used by Thompson et al. (2001). One subtest was a speeded test of pattern-matching abilities, the other a test of working memory. The tempo (fast) and mode (major) of the Mozart piece were likely to make it more arousing and pleasant than listening to Albinoni (Husain et al., 2002; Thompson et al., 2001). According to the arousal and mood hypothesis, if the pieces evoke differential emotional responding (i.e. in arousal and/or mood), we should also find evidence of a Mozart advantage on one or both of the IQ subtests.

In Experiment 2, we tested the creative abilities of Japanese 5-year-olds after they were exposed to classical music (Mozart or Albinoni) or to familiar children's music (listening or singing). Our goals were to test three predictions motivated by the arousal and mood hypothesis. One was to examine whether effects of exposure to music on cognition generalize to listeners from a different culture and age group. The second goal was to examine whether such effects would generalize to tests of creativity. Although creativity is typically considered to be an aspect of complex cognition (e.g. Sternberg and Ben-Zeev, 2001), our measures of creativity differed markedly from IQ subtests (e.g. the WAIS-III subtests used in Experiment 1, the paper-folding-and-cutting subtest from the Stanford-Binet IQ test used in previous research). The third goal was to examine the specific type of musical experiences that enhance cognition. We assumed that songs written specifically for young children would be more likely than classical music to be optimally arousing and pleasant for this age group, and that singing familiar children's music might be as effective as listening in this regard. Thus, we expected that the best performance on the creativity measures would follow exposure to familiar children's music.

Experiment 1

Experiment 1 was similar in design to that of Thompson et al. (2001) except that the cognitive tests did *not* measure spatial–temporal abilities. Undergraduates listened to music composed by Mozart or Albinoni and subsequently completed one of two IQ subtests. Arousal and mood were measured before and after music listening.

METHOD

Participants

Forty-eight Canadian undergraduates (77% women) who were registered in an introductory psychology course participated in exchange for partial course credit. The students were young adults 18 to 23 years of age from a variety of cultural and ethnic backgrounds (European: 54%; East Asian: 15%; Hispanic: 13%; South Asian: 11%; African: 4%; Middle Eastern: 2%) that mirrored the make-up of the local community.

Apparatus, stimuli, and measures

Participants were tested in a sound-attenuating booth. They wore high-quality stereophonic headphones (SONY MDR-P1) while sitting in front of an iMac computer. The music consisted of 10 minutes of an up-tempo piece played in a major key (Mozart's *Sonata for Two Pianos in D Major K 448*), or 10 minutes of a slow piece written in a minor key (Albinoni's *Adagio in G Minor for Strings and Organ*). The music was excerpted from commercial recordings available on compact disk and stored digitally as CD-quality sound files.

Arousal and mood were measured with the Profile of Mood States – Short Form (POMS; McNair et al., 1992). The scale has six subscales; as in Thompson et al. (2001), our interest was limited to two of these (Vigor–Activity – a measure of arousal, and Depression–Dejection – a measure of negative mood).

The cognitive tasks were two subtests from the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997). They were selected because both could be adapted easily for computer presentation but neither measured spatial–temporal (nor spatial) abilities. One was Symbol Search, a speeded pattern-matching task that is one of two subtests used to derive the Processing Speed index score of the WAIS-III. Respondents were asked to complete as many items as possible within 2 minutes. For each item, they identified (i.e. YES or NO) whether either of two target symbols (on the left side of the monitor) was present in a horizontal array of five symbols (on the right side). The number of correct responses minus the number of incorrect responses was converted to a standard score that is normed according to age ($M = 10$, $SD = 3$).

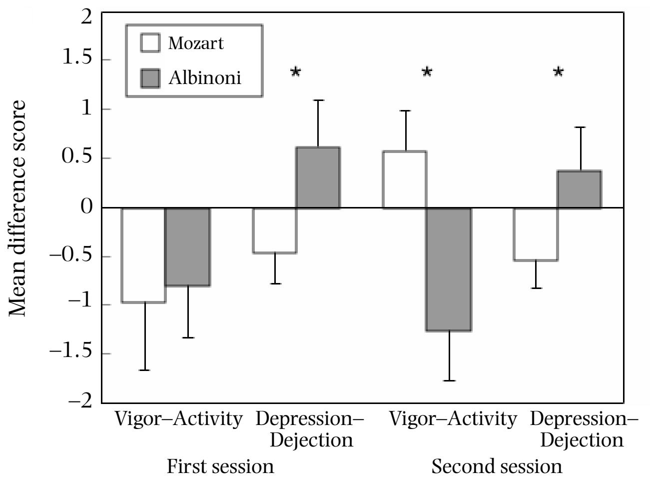
The other subtest was Letter–Number Sequencing, one of three subtests that form the Working Memory index score of the WAIS-III. On each trial, participants saw an alternating sequence of letters and numbers presented in the center of the monitor (one per second). Their task was to recall the sequence by typing it in a rearranged order: the numbers in ascending order followed by the letters in alphabetical order. For example, if the sequence was R-6-B-3, the correct response was 3-6-B-R. The task became progressively harder, with the easiest level having two items on each of three trials and the most difficult level having eight items. The number of correct responses (excluding those made after the participant had three errors on a single level) was converted to a standard, age-normed score ($M = 10$, $SD = 3$).

Procedure
Participants were tested individually on two occasions separated by no more than one week. On each occasion, they completed a paper-and-pencil version of the POMS. They then entered the booth where they heard 10 minutes of music, followed immediately by one of the two cognitive tests. After exiting the booth, they completed the POMS again.

The music was the Mozart piece on one occasion and the Albinoni piece on the other. The cognitive task was Symbol Search on one occasion and Letter–Number Sequencing on the other. Music order (Mozart then Albinoni or vice versa) and test order (Symbol Search then Letter–Number Sequencing or vice versa) were counterbalanced.

RESULTS AND DISCUSSION

The first set of analyses examined changes in arousal and mood as a function of music listening (Mozart or Albinoni). We used one-tailed tests because we had specific, directional hypotheses that were supported by the results of a previous study (Thompson et al., 2001). Difference scores (post-music minus pre-music) were calculated separately for the Vigor–Activity (arousal) and Depression–Dejection (mood) subtests, and for the first and second test sessions (see Figure 1). Independent-samples *t*-tests revealed that the mood measure exhibited a small but reliable difference due to music listening at the first test session, $t(46) = 1.89$, $p = .033$, $\eta^2 = .07$. As shown in Figure 1, Depression–Dejection scores increased after listening to Albinoni but decreased after listening to Mozart. There was no effect of music listening on arousal during the first session (see Figure 1; Vigor–Activity scores decreased in both conditions). Perhaps the unfamiliarity of the testing environment interfered with effects of the music manipulation on arousal in this instance.



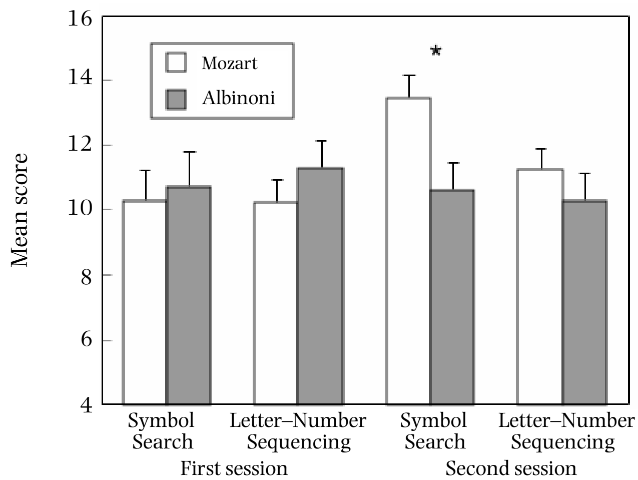
Notes
*Significant effect of music listening (one-tailed tests).
Error bars are standard errors.

FIGURE 1 *Mean difference scores on the arousal and mood measures in Experiment 1.*

At the second test session, both the mood measure, $t(46) = 1.75$, $p = .043$, $\eta^2 = .06$, and the arousal measure, $t(46) = 2.77$, $p = .004$, $\eta^2 = .14$, varied reliably as a function of the different music-listening experiences. Depression–Dejection scores increased after listening to Albinoni but decreased after Mozart, whereas Vigor–Activity scores increased as a consequence of listening to Mozart but decreased after Albinoni (see Figure 1).

The next set of analyses examined scores on the IQ subtests as a function of music listening (see Figure 2). Because arousal *and* mood differed at the second session but only mood varied reliably at the first session, cognitive differences between conditions were expected to be stronger at the second session compared to the first. Indeed, neither Symbol Search nor Letter–Number Sequencing scores varied as a function of music listening at the first session. At the second session, Symbol Search scores were higher after listening to Mozart than after listening to Albinoni, $t(22) = 2.75$, $p = .012$ (two-tailed), $\eta^2 = .26$, but there was no effect for Letter–Number Sequencing. A previous study (Steele et al., 1997) also found that there was no enhancement of working memory after participants listened to Mozart.

In sum, when differences in arousal and mood were evident as a consequence of music listening (second session), a reliable difference on one of two IQ subtests was also evident. When there was only a small difference in mood but no effect on arousal (first session), there were no differences in cognitive abilities. These findings have important ramifications for the arousal and mood hypothesis. First, they suggest that subtle contextual differences may moderate effects of music listening on arousal more than on mood. They also indicate that some cognitive tests may be more susceptible



Notes:
*Significant effect of music listening (two-tailed test).
Error bars are standard errors.

FIGURE 2 *Mean standard scores on the IQ subtests in Experiment 1.*

than others to influences of arousal and mood. Finally, they provide evidence that cognitive byproducts of music listening depend more on arousal than on mood, as suggested earlier. Alternatively, such byproducts may be more likely when music listening evokes simultaneous changes in arousal *and* mood rather than a change in either arousal *or* mood.

Experiment 2

In Experiment 2, the participants were 5-year-old Japanese children and the outcome variables were measures of creativity. At an initial session to establish baseline measures of creativity, each child was asked to make a drawing. After a musical experience, the children made a second drawing. Two groups of children drew after listening to the Mozart or the Albinoni piece used in Experiment 1. A third group *heard* familiar children's songs before they drew. A fourth group *sang* familiar songs before drawing. The outcome measures included drawing times and adults' ratings of creativity, energy, and technical proficiency for the children's drawings (see Loveland and Olley, 1979). Although there is no self-report measure of arousal and mood that can be used with young children, the results of Experiment 1 and earlier studies made it relatively safe to assume that any observed links between music listening and cognition would be mediated by arousal and mood.

METHOD

Participants

The participants were 39 5-year-old Japanese children (13 boys, 26 girls) from two kindergarten classes. An additional three children were recruited but excluded from the final sample because of lack of interest in the drawing task ($n = 2$) or conflict with another child ($n = 1$). A subgroup of 9 to 11 children was selected randomly to draw after they had listened to Mozart ($n = 11$), Albinoni ($n = 10$), or familiar children's songs ($n = 9$), or after they had sung familiar songs ($n = 9$). Eighteen female undergraduates – who were blind to group membership – volunteered to rate the children's drawings.

Apparatus, stimuli, and measures

The children were tested in classrooms at the kindergarten they attended. In two of the listening sessions, the recorded music consisted of one of the two pieces from Experiment 1 (Albinoni's *Adagio in G Minor for Strings and Organ*; Mozart's *Sonata for Two Pianos in D Major K 448* – a different recording of the same piece). In the familiar-listening session, the music comprised 16 children's songs from commercially available recordings (see Table 1) that the children had learned to sing at school. The children's songs had Japanese lyrics but they were all in Western major keys with a regular metrical structure. Two of these 16 songs were sung by the children in the familiar-singing session (see Table 1).

TABLE 1 *Children's songs used in the familiar-listening session in Experiment 2 (English translation in parentheses)*

Ashita-wa-hareru (Tomorrow will be a fine day)*
Yakiimo-no-uta (Baked potato song)*
Panda, usagi, koala (Panda, rabbit, koala)
Hoshi-no-Carnival (Carnival of the stars)
Fushigi-na-pocket (Mysterious pocket)
Kobutanukitsuneko (Little pig, raccoon, dog, fox, and cat)
Kon-kon-kushan-no-uta (Sneezing song)
Ookina kuni-no kino shita de (Under a tree in a big country)
Zo-san (Elephant)
Ice cream no uta (Ice cream song)
Tyoo-tyo (Butterfly)
Tulip (Tulip)
Koinobori (A carp streamer)
Tombo-no-megane (Dragonfly's glasses)
Matsu bokkuri (A pinecone)
Donguri-korokoro (Acorns rolling down)

*Songs used in the familiar-singing condition.

Recordings were played on a portable CD player (AIWA CSDSR520) at a comfortable volume. A piano was used to accompany the children when they sang. Drawing times were measured with a handheld stopwatch.

Procedure

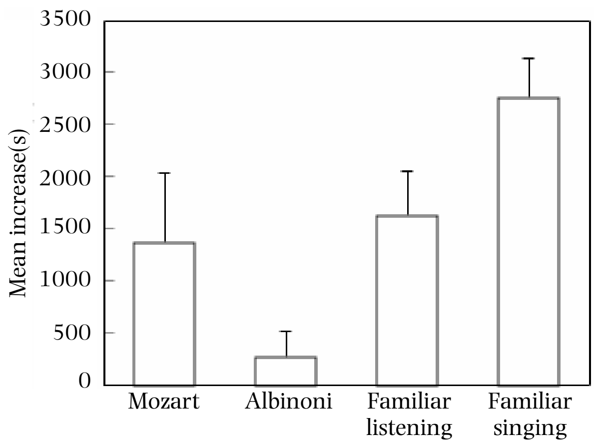
Each child made an initial baseline drawing that did not follow a musical experience, and a second drawing after one of the four musical experiences. An assistant recorded drawing times in both sessions. In the initial (baseline) session, children were provided with paper and 18 crayons after having lunch with their classmates (no music). They were asked to draw anything they wanted. Music sessions were scheduled subsequently, each separated by 2 or 3 days.

After each music session, a subset of children was selected randomly to draw for a second time. In the first session, children heard the Mozart piece presented repeatedly for an hour while they ate lunch with their classmates. In the second session, children heard Albinoni for an hour during lunch. In the third session, one of the two kindergarten classes sang two familiar songs for 20 minutes after lunch while a teacher provided piano accompaniment and an experimenter (the fourth author) sang along. The other class heard 16 children's songs for an hour during lunchtime in the third session, and sang two familiar songs in a fourth session.

The adult raters were required to compare the two drawings (baseline and music) from each child on each of three different scales (creativity, energy, and technical proficiency). For each scale, the rater was asked to provide a rating of 1 if the drawing on their left was substantially more creative (or energetic or technically proficient) than the one on their right, and a rating of 6 if the drawing on their right was substantially more creative (or energetic or technically proficient). Hence, the ratings were difference (or comparison) scores. Picture location (baseline/left-music/right or vice versa) and order of the 39 children's drawings were randomized separately for each rater. Ratings were reverse coded when the music drawing was on the left so that ratings were comparable across children and raters, with higher numbers representing higher ratings for the music drawing compared to baseline.

RESULTS AND DISCUSSION

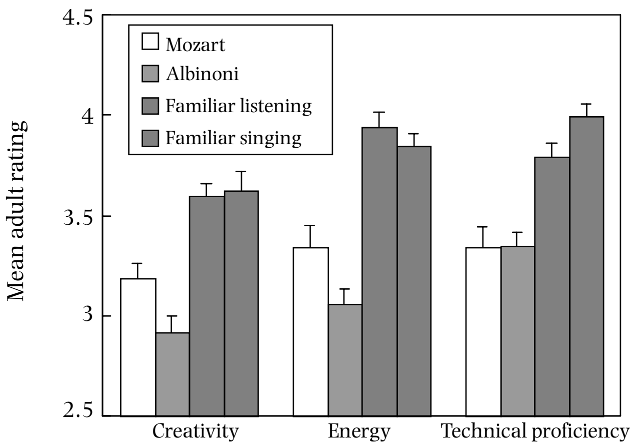
For each outcome measure, the principal analytic strategy was to compare the four groups of children with analysis of variance (ANOVA) followed by planned orthogonal contrasts (classical vs familiar music, listening to fast–major vs slow–minor classical music, singing vs listening to familiar music). The first set of analyses examined drawing times. For each child, we calculated a difference score (music condition minus baseline, see Figure 3). Preliminary one-sample t-tests revealed that drawing times increased reliably from baseline after listening to familiar music, $t(8) = 3.99$, $p = .004$, and after singing familiar music, $t(8) = 7.56$, $p < .001$. Drawing times did not increase for children who heard Albinoni or Mozart. Time spent drawing varied reliably across conditions, $F(3, 35) = 4.59$, $p = .008$, $\eta^2 = .28$, with greater increases in the two familiar-music conditions than in the two classical-music conditions, $F(1, 35) = 8.55$, $p = .006$. The two familiar-music conditions did not differ, nor did the two classical-music conditions.



Note: Error bars are standard errors.

FIGURE 3 *Mean increase in drawing times in Experiment 2.*

The next set of analyses examined adults' ratings of the children's drawings (see Figure 4). For each adult, four creativity scores were formed, each representing the average rating calculated separately for each of the four groups of children. Four energy scores and four technical proficiency scores were formed identically. Creativity ratings varied across the four conditions, $F(3, 51) = 19.27$, $p < .001$, $\eta^2 = .53$, as did energy ratings, $F(3, 51) = 25.59$, $p < .001$, $\eta^2 = .60$, and technical proficiency ratings, $F(3, 51) = 13.47$, $p < .001$, $\eta^2 = .44$. In each case, ratings were higher for drawings from the familiar-music compared to the classical-music conditions, as predicted (for creativity, energy, and technical proficiency, respectively, Fs(1, 17) = 42.58, 78.57, and 37.13, ps < .001). An advantage for Mozart over Albinoni was also evident for creativity ratings, $F(1, 17) = 6.34$, $p = .022$; the same advantage was marginal for energy ratings ($p = .063$) but non-significant for technical proficiency ratings. Presumably, when evident, the Mozart advantage was a consequence of its faster tempo. The two familiar-music conditions did not differ on any of the three rating scales.



Notes
Error bars are standard errors.
Scores above or below the scale midpoint (3.5) indicate higher ratings for the music or baseline drawings, respectively.

FIGURE 4 *Mean creativity, energy, and technical proficiency ratings made by adults of the children's drawings in Experiment 2.*

In sum, compared to children who drew after hearing Mozart or Albinoni, children exposed to familiar songs had longer increases in drawing times relative to baseline. Moreover, their post-music drawings were considered by adults to be more creative, energetic, and technically proficient. The results also indicated that *listening* to familiar songs and *singing* them are similarly effective in enhancing creativity among young children.

General discussion

In these two experiments, we found evidence that effects of music listening extend beyond measures of spatial–temporal ability. In Experiment 1, Canadian adults listened to music composed by Mozart or Albinoni and subsequently completed an IQ subtest. When the listening experience led to a difference in arousal and mood (favouring Mozart), a parallel difference on an IQ subtest was also evident (favouring Mozart). These findings are consistent with the proposal that music-enhanced cognitive performance is a byproduct of arousal and mood. They also refute suggestions of a special link between listening to Mozart and spatial–temporal abilities. Although the results indicate that some cognitive tests are more influenced by exposure to music than others, spatial–temporal status is not a prerequisite for such effects to emerge.

The results of Experiment 2 indicated that cognitive enhancement after music listening extends to tests of creativity, and that such enhancement depends on the match between the music and the listener. Specifically, Japanese 5-year-olds were asked to make drawings either after listening to classical music or after hearing or singing familiar children's songs. Each measure of creativity (i.e. drawing times; adults' ratings of creativity, energy, and technical proficiency) revealed better performance after the familiar songs compared to the classical recordings. In other words, cognitive effects of exposure to music extended to young Asian children and tests of creativity, and generalized across modality of exposure.

The present findings help to explain previous failures to replicate the Mozart effect (e.g. Carstens et al., 1995; Hallam, 2000; McCutcheon, 2000; McKelvie and Low, 2002; Newman et al., 1995; Steele et al., 1997; Steele, Bass et al., 1999; Steele, Brown et al., 1999; Steele, Dalla Bella et al., 1999; Stough et al., 1994), which are as common as successes (e.g. Husain et al., 2002; Ivanov and Geake, 2003; Nantais and Schellenberg, 1999; Rauscher et al., 1993, 1995; Rideout et al., 1998; Rideout and Taylor, 1997; Thompson et al., 2001; Wilson and Brown, 1997; for reviews, see Chabris, 1999; Hetland, 2000). First, our results suggest that the effect is somewhat ephemeral. In Experiment 1, music listening led to reliable differences in arousal, mood, and cognitive performance on participants' second visit to the laboratory; only mood differences were evident on their first visit. Second, in many studies (e.g. Steele, Dalla Bella et al., 1999), undergraduates are tested as groups in classroom settings, where interpersonal dynamics could play a role while students are listening to Mozart or sitting in silence. Specifically, these dynamics (e.g. students rolling their eyes, giggling) could influence the emotional state of the participants directly, or interfere with changes in state that might otherwise result from music listening. Third, in McKelvie and Low's (2002) study of 12-year-olds (see also Hallam, 2000), the lack of an effect of listening to Mozart on a spatial–temporal task may have stemmed from the music and task – both less than ideal for this age group. In some instances, relatively fast-tempo classical music may indeed be more emotionally stimulating for children than slow music (Experiment 2) or silence (Ivanov and Gleake, 2003), but our results indicate that age-appropriate music is more effective in this regard.

To conclude, there is no merit to the claim of a link between listening to music composed by Mozart to the exclusion of music by other composers, and spatial–temporal abilities to the exclusion of other cognitive abilities. Similar effects are generated by other forms of music (as well as nonmusical stimuli), and the effects can be explained by mediating effects of arousal and mood. The present findings clarify that such effects extend to cognitive tests without spatial–temporal status, and across participants who differ in age and cultural background. The Mozart effect is simply one example of the many ways that emotional state influences cognitive processing.

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