Music Lessons and Intelligence: A Relation Mediated by Executive Functions
Author(s): Franziska Degé, Claudia Kubicek and Gudrun Schwarzer
Source: *Music Perception: An Interdisciplinary Journal*, Vol. 29, No. 2, Music Training and Nonmusical Abilities (December 2011), pp. 195-201
Published by: University of California Press
Stable URL: http://www.jstor.org/stable/10.1525/mp.2011.29.2.195
Accessed: 25/05/2015 05:40

Music Lessons and Intelligence: A Relation Mediated by Executive Functions

Franziska Degé, Claudia Kubicek, & Gudrun Schwarzer
Justus-Liebig-University, Gießen, Germany

The present study investigated whether the association between music lessons and intelligence is mediated by executive functions. Intelligence and five different executive functions (set shifting, selective attention, planning, inhibition, and fluency) were assessed in 9- to 12-year-old children with varying amounts of music lessons. Significant associations emerged between music lessons and all of the measures of executive function. Executive functions mediated the association between music lessons and intelligence, with the measures of selective attention and inhibition being the strongest contributors to the mediation effect. Our results suggest that at least part of the association between music lessons and intelligence is explained by the positive influence music lessons have on executive functions, which in turn improve performance on intelligence tests.

Received June 6, 2011, accepted July 24, 2011.

Key words: music lessons, intelligence, executive functions, children and music, cognitive development

The question of whether music improves intelligence has intrigued researchers, music educators, and parents all over the world. This issue received a great deal of media attention after Rauscher, Shaw, and Ky (1993) reported that listening to Mozart improved performance on the spatial subscales of an IQ test, a finding referred to as the "Mozart Effect." It was later demonstrated, however, that this finding was due not to the effect of music but to the positive arousal state caused by listening to music (Thompson, Schellenberg, & Husain, 2001). Listening to a Stephen King story also improved performance on a spatial task when participants enjoyed the listening experience (Nantais & Schellenberg, 1999).

Although there is no evidence that listening to music improves IQ, there is evidence that learning to play music improves IQ. In two comprehensive studies, Schellenberg (2004, 2006) demonstrated that music lessons increased intelligence, and that these increases were long-lasting and independent of socioeconomic status. Nonetheless, the nature of the association between music training and IQ is not completely understood. It remains unclear whether the association is direct or mediated by a third variable. In the present study, we investigated whether executive functions serve as mediators. Executive functions may be potential mediators because they are related to intelligence (Ardila, Pineda, & Rosselli, 2000), associated with music lessons (Bialystok & DePape, 2009), and trainable (Zelazo, Carlson, & Kesek, 2008).

One ongoing debate concerns whether associations between music lessons and cognition are general or specific to certain domains of cognition. Music training is associated positively with improvements in reading (Moreno et al., 2009), spatial reasoning (Rauscher et al., 1997), mathematics (Cheek & Smith, 1999), short-term memory (Degé, Wehrum, Stark, & Schwarzer, 2011), and attention (Scott, 1992). Findings of associations across different domains raise doubts about claims of specificity, as do findings of associations between music training and full-scale IQ (Schellenberg, 2004, 2006, 2011), and other results pointing to an association between music training and domain-general abilities such as mental speed (Gruhn, Galley, & Kluth, 2003).

In a study by Schellenberg (2006), 6- to 11-year olds and first-year undergraduates with varying amounts of music lessons were given the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991) and the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997), respectively. Information was also collected about duration of music lessons, involvement in nonmusical out-of-school activities, and socioeconomic status (SES; as measured by parents' education and family income). A positive association between duration of lessons and intelligence was found even when SES and involvement in nonmusical out-of-school activities were held constant. For the children, six years of music lessons were associated with an increase of 7.5 IQ points. The

Music Perception volume 29, issue 2, pp. 195–201. issn 0730-7829, electronic issn 1533-8312. DOI: 10.1525/mp.2011.29.2.195

association was not as strong for the undergraduates, for whom six years of music lessons were associated with an increase of only 2 points.

Of course, even well controlled correlational designs do not allow for inferences regarding the direction of causation. Although music lessons could lead to intellectual benefits, it is also possible that children who take music lessons are inherently more intelligent than those who do not take lessons or persist in their training. Schellenberg (2004) conducted an experimental study examining the effects of music training on IQ, in which 6-year-olds were assigned randomly to keyboard lessons, voice lessons, drama lessons, or no lessons. Children were given the WISC-III at the beginning and end of first grade, with 36 weeks of lessons (or no lessons) in the interim. The combined music (keyboard and voice) groups displayed significantly greater increases in full-scale IQ compared to the combined control (drama and no lessons) groups, a difference of almost 3 points. This effect was not due to improvements in particular IQ subtests because similar increases for the music groups occurred across all four indices of the WISC-III, suggesting that music lessons caused modest improvements in general intelligence.

Although the study's experimental design allowed for inferences of causation, it was not carried out under naturalistic conditions. Because parents did not pay for the music lessons, they may have been less motivated to encourage practicing, which could explain the fact that the children in this study practiced minimally (Schellenberg, 2011). Moreover, it is exceedingly difficult to study effects of long-term music lessons using an experimental design because children cannot be "forced" to continue taking lessons over a number of years. Thus, in order to study long-term effects of music lessons in an ecologically valid situation, we may have to study children who self select into music lessons while controlling for as many variables as possible, as in Schellenberg (2006).

Although Schellenberg (2004) found a causal association between music lessons and intelligence, the mechanism underlying this association remains unclear. In the present study, we investigated whether music lessons enhance IQ in children by improving executive functions. According to this hypothesis (Hannon & Trainor, 2007; Schellenberg & Peretz, 2008), executive functions represent a set of mediating mechanisms through which the predictor variable of music lessons influences the outcome variable of intelligence. Because executive functions play a positive role in nearly all cognitive tasks and abilities (Hannon & Trainor, 2007) and playing music involves daily use of selective attention, switching, inhibition, and monitoring (Jäncke, 2009)—all of which are aspects of executive functions—executive functions could mediate the established association between music lessons and intelligence.

If executive functions serve as such a mediator, they must correlate with both the predictor variable (music lessons) and the outcome variable (intelligence). There is evidence for both of these links. Executive functions have been found to be related to musical performance and training (Bialystok & DePape, 2009; Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007b). For example, Bialystok and DePape (2009) compared bilingual nonmusicians, monolingual musicians, and monolingual nonmusicians on executive function tasks that measured response inhibition (the Simon Arrows task and the Auditory Stroop task). Both bilingual individuals and musicians exhibited superior performance on the Simon Arrows task. The musicians outperformed bilingual individuals, and the monolingual nonmusicians on the Auditory Stroop task. Moreover, when Bugos et al. (2007) randomly assigned older adults to 6 months of individualized piano instruction or to a control group, they found an association between music instruction and a measure of set shifting (the Trail Making Test), as well as an association between music training and a measure of processing speed (Digit-Symbol Coding). Executive functions are also known to be associated with intelligence. For example, Ardila et al. (2000) reported associations between full-scale IQ and fluency, and between IQ and set shifting. In short, theoretical and empirical perspectives provide support for the hypothesis that executive functions serve as potential mediators of the association between music lessons and intelligence.

The first study testing this mediation hypothesis was conducted by Schellenberg (2011). He assessed intelligence (WASI; Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999) and executive functions (working memory, phonological fluency, mental flexibility, inhibition, and planning) in a sample of 9- to 12-year-olds. Half of the children had music training and half had no training. The children with music training exhibited significantly better performance than the untrained group on the measure of IQ. For the measures of executive function, however, performance of the trained children was significantly better than the untrained children only for working memory. In addition, regression analysis revealed that music training continued to account for variance in intelligence even after executive functions were held constant. If executive functions had mediated the effect, the association between music training and intelligence should have decreased or disappeared. In short, Schellenberg found no evidence that executive functions mediate the association between music lessons and intelligence.

Nevertheless, a null finding cannot be interpreted unequivocally. We therefore introduced several methodological changes in the present study to sort out the issue of mediation. As in Schellenberg (2011), we investigated associations among music training, executive functions, and IQ in a group of 9- to 12-year-old children with varying amounts of music lessons. In contrast to Schellenberg's study, we used a continuous rather than a categorical measure of music training. Moreover, the measures of executive function were designed specifically for children and included a test of attention, which is sometimes identified as the basis of executive function (Garon, Bryson, & Smith, 2008; Miyake et al., 2000). IQ was assessed with a test of fluid intelligence, instead of using a test measuring fluid and crystallized intelligence. We hypothesized that months of music lessons would predict performance on tasks assessing executive functions, which, in turn, would predict higher performance on a measure of fluid intelligence. We also expected that when executive functions were held constant, any direct association between music lessons and intelligence would be reduced or eliminated.

Method

Participants

The sample comprised 90 9- to 12-year-olds (41 boys, 49 girls; mean age = 137 months; SD = 10). The children varied widely in months of music lessons: 32.6% reported receiving no music lessons (except for music as a school subject), 50.0% reported 1 to 4 years of instrumental music lessons (no voice lessons), and 17.4% reported more than 4 years of instrumental lessons. Girls (M = 36 months, SD = 37) had significantly more formal music training than boys (M = 19 months, SD = 22), $t(80.10) = 2.61$, $p = .014$ (Levene's test revealed significant differences in variance between the two groups, $p = .001$). There was no difference in fluid intelligence between boys (M = 104, SD = 14) and girls (M = 102, SD = 10), $p > .3$. For 30%, 31%, and 39% of the children, respectively, neither parent had a university degree, one parent had a university degree, or both parents had a university degree. Boys were significantly more likely than girls to have a parent with a university degree, $t(88) = 3.33$, $p = .001$.

Materials and Procedure

Parents completed a questionnaire that asked for information about demographic variables and the extent of the child's music training. Duration of music lessons in months for each child was determined from questions about current and former music education. When a child played more than one instrument, the number of months of instruction for each instrument was combined. Mothers' and fathers' education was initially coded as a dichotomous variable (0 for "no university degree" and 1 for "a university degree"); for the statistical analyses, parents' education was collapsed into a single variable (0, 1, or 2 parents with a university degree). To provide a second measure of socioeconomic status, monthly family income was assessed using a four-point scale ranging from less than 1000€ per month to more than 3000€ per month.

Executive functions were assessed using the attention and executive function domain of the NEPSY II, a developmental neuropsychological assessment for children (Korkman, Kirk, & Kemp, 2007). Subtests included measures of set shifting, selective attention, planning, inhibition, and fluency. Age-corrected scores were used when scoring each subtest. When a subtest had more than one outcome measure, integration rules provided by the NEPSY II were used to obtain a single score for each child.

Set shifting was assessed with the "animal sorting" task, a card sorting procedure that assessed the ability to generate categories, to use these categories as a basis for action, and to shift from one category to another. The animal cards differed in features such as color (blue or yellow), number of animals on a card (one or several), or weather (sunny or rainy), and these differences formed the basis for generating categories. Altogether, 12 different features could be used to sort the eight cards into two different groups. Children were asked to sort repeatedly the eight cards into two groups of four cards based on a particular feature. One point was scored for each of the 12 possible sorts that were completed within the 6 minute time limit. An error score was calculated based on repeating sorts (i.e., the same groups were generated more than once) or sorts that were not based on a given common feature. Correct responses and error scores were combined to provide a single set-shifting score for each child.

Selective attention was measured with the "auditory attention and response set" task. The first part of the assessment, "auditory attention," assessed selective attention; the second part, "response set," assessed set shifting. Although children completed both parts, only the selective attention score was included in the statistical analyses because we already had a measure of set shifting (described above). In the auditory attention task, children wore headphones and listened to a series of words played on a portable CD player. They were instructed to touch a red circle whenever they heard the word "red." One point was scored for each correct response that occurred within 2 seconds. When a child responded more than 2 seconds after the target or produced an incorrect response, the response was coded as an error. Correct responses and errors were combined to provide a single score of selective attention for each child.

Planning and organization abilities were assessed by the "clocks" subtest. In the drawing condition, children were asked to draw a clock and to place the hands where the examiner indicated. In the visual condition, children were asked to read the time on clocks that either did or did not have numbers. In the drawing condition, the presence, location, and sequence of the numbers, the presence, accommodation, closure, and symmetry of the contour, the presence, connection, proportion, and correct targeting of the hands, and the presence and location of the center were all scored. For number sequence and correct targeting of the hands, two points were scored for a correct response and one point for a response that was almost correct. For the other criteria, a correct response received one point. In the visual condition, one point was scored if the reported time was correct; incorrect responses were not scored. A single score of planning and organization was calculated for each child as the total number of points.

Inhibition was assessed with the "inhibition" subtest, which assessed the ability to inhibit automatic responses in favor of novel responses. In the shape condition, children were instructed to say "square" every time they saw a circle, and "circle" every time they saw a square. In the arrow condition, they were instructed to say "up" for every arrow pointing down and "down" for every arrow pointing up. For both conditions, uncorrected and self-corrected errors were summed to yield an error score. The child's completion time within the 4-minute limit for the task was also measured. Error scores and completion times were combined to provide a single score of inhibition for each child.

Fluency was measured with the "design fluency" subtest, which assessed the ability to generate multiple unique designs by connecting up to five dots presented in either structured or random arrays. Children were asked to draw as many designs as possible in each array within 60 seconds. Each correct design scored one point. A design was considered correct if all the lines were straight, any gaps between a dot and a line were less than 2 mm, and the design did not simply repeat one that had already been drawn. A single fluency score for each child was represented by the total number of points achieved.

Fluid intelligence was measured with the revised form of the Culture Fair Test (Weiss, 2006). Both parts of the CFT 20-R were administered to achieve higher reliability. Each part consisted of the same four subtests (series, classification, matrices, topologies). Age norms were used to calculate an IQ score for each participant.

Families were mailed a questionnaire prior to the test sessions. Parents were asked to complete the questionnaire and to bring it with them to the first session. In the first session, children were tested individually, and executive functions were assessed by a trained female assistant unaware of the extent of the child's music training. Tasks were administered in the following order: set shifting, selective attention, planning, inhibition, and fluency. Children returned for a second session to complete an intelligence test administered by the same assistant, but the test was administered in groups. After the second session, each child received a gift certificate to a local toy shop to thank them for their participation.

Results

Months of music lessons were significantly correlated with IQ, $r(88) = .27$, $p = .01$. The association between music lessons and IQ remained significant when gender, parents' education, and family income were held constant, $pr(85) = .28$, $p = .009$. As shown in Table 1, all measures of executive functions were correlated positively with one another, with correlation coefficients ranging from $r = .35$ to $r = .55$. As shown in Table 2, each measure of executive function was correlated with music lessons and with IQ.

Hierarchical multiple regression analysis was used to predict IQ scores with demographic variables entered on the first step, executive functions added on the second step, and music lessons added on the third step. The demographic variables accounted for only 3.6% of the variance in IQ, $p > .30$, and no variable contributed significantly, $ps > .10$. The addition of the five measures of executive function improved the fit of the model, $F_{inc}(5, 81) = 15.68$, $p < .001$, accounting for an additional 47.4% of the variance in IQ. Selective attention, $p < .01$, and inhibition, $p < .01$, made significant unique contributions to the model, whereas set shifting and planning made marginal contributions, $ps < .10$. The addition of

TABLE 1. Correlations Among Measures of Executive Function.

	Selective Attention	Planning	Inhibition	Fluency
Set Shifting	.38**	.40**	.38**	.41**
Selective Attention		.36**	.35**	.48**
Planning			.50**	.43**
Inhibition				.55**

Note. ** $p < .001$

TABLE 2. Correlations Between Measures of Executive Function and Months of Music Lessons and IQ.

	Duration of Music Lessons	IQ
Set Shifting	.39**	.48**
Selective Attention	.37**	.47**
Planning	.41**	.47**
Inhibition	.34**	.57**
Fluency	.45**	.45**

Note. ** $p < .001$

music lessons on the third step did not improve explanatory power any further, $p > .50$. In fact, the partial slope was negative (but not significant). More specific tests of the two significant executive function predictors revealed significant mediation effects of selective attention $z = 2.05$, $p < .05$, and inhibition $z = 2.19$, $p < .05$. In short, executive functions—in particular selective attention and inhibition—mediated the association between music lessons and IQ even when gender, parents' education, and family income were held constant.

Discussion

We tested the hypothesis that the association between music lessons and intelligence is mediated by executive functions. Executive functions, fluid intelligence, and duration of music lessons were assessed in a sample of 9- to 12-year-olds. Duration of music lessons was significantly related to all measures of executive function, with music lessons explaining between 12-20% of the variance in each measure. The hypothesis that the association between music lessons and intelligence was mediated by executive functions was confirmed, with the measures of selective attention and inhibition being the strongest contributors to the mediation effect.

These results are consistent with the argument that daily practice of instrumental music enhances executive functions (Jäncke, 2009) and with prior findings that music training is predictive of higher levels of inhibitory control (Bialystok & DePape, 2009). Our study replicated Bialystok and DePape's finding that music training was related to inhibition and extended this finding to include selective attention, set shifting, planning, and fluency. The present study also replicated, with children, Bugos et al.'s (2007) finding with older adults that music training was associated with set shifting.

The finding that executive functions mediated the association between music lessons and IQ suggests that music lessons influence intelligence indirectly rather than directly, and provides support for the hypothesis that music lessons enhance IQ by strengthening children's executive functions (Hannon & Trainor, 2007; Schellenberg & Peretz, 2008). The fact that executive functions are involved in successful completion of nearly all cognitive tasks (Hannon & Trainor, 2007) is also consistent with Schellenberg's (2004, 2006) findings that music lessons affect IQ generally rather than affecting specific components of IQ.

In contrast to the present results, Schellenberg (2011) found no support for the hypothesis that executive functions mediate the association between music lessons and IQ. What accounts for differences between the positive findings of the present study and Schellenberg's null findings? As noted, the studies differ in several important respects. The present study used a continuous measure —months of music lessons—which is more informative than a categorical measure by taking into account individual differences in amount of music training. The present study also used measures of executive function that were designed explicitly for the neuropsychological assessment of children, whereas one of Schellenberg's measures was the Wisconsin Card Sorting Test, which was designed originally for neuropsychological assessment in adults (although his other executive function measures, such as the Tower of Hanoi, were suitable for children). Perhaps our measures of executive function designed explicitly for children were also more engaging.

Another possible explanation for the difference in findings between studies is our use of the NEPSY II, which provided age-scaled scores for executive functions and a single aggregated score for each subtest. Thus, it was not necessary to decide which outcome measure to include in the analysis or to conduct a factor analysis to aggregate the scores, as Schellenberg (2011) did. Our use of age-scaled scores also made it unlikely that age effects, which are quite likely among children who range in age from 9 to 12 years, overshadowed the associations under investigation. Further, the present study assessed the executive function of selective attention, which was found to contribute significantly to the mediation effect, whereas Schellenberg had no direct measure of selective attention.

Finally, findings of the two studies may have differed due to differences in the measures used to assess intelligence. Schellenberg (2011) used a composite measure that included both fluid and crystallized intelligence, whereas the present study used a measure of fluid intelligence. Executive functions are processes that enable conscious and goal-directed problem solving (Zelazo et al., 2008). They are more similar to fluid intelligence, an all-purpose, content-independent cognitive processing ability (Blair, 2006), than to crystallized intelligence. The similarity between fluid intelligence and executive functions undoubtedly strengthens the association between intelligence and executive function, thereby increasing the power to uncover a mediation effect. Using a test of fluid intelligence also has disadvantages, however, because other studies reported no reliable links between music training and fluid intelligence (Bialystok & DePape, 2009; Brandler & Rammsayer, 2003; Helmbold, Rammsayer, & Altenmuller, 2005; Schellenberg & Moreno, 2010). In other words, a measure of fluid intelligence might not represent the association between music lessons and intelligence as well as a combined measure of fluid and crystallized intelligence. Compared to the relatively small association with fluid intelligence reported here, Schellenberg (2011) found a much greater association between music training and combined (crystallized and fluid) intelligence, which would be more difficult to eliminate with a mediator. Clearly, further investigation is needed to resolve these issues.

It is important to note that the correlational design of the present study does not allow for inferences of causation. Selection effects cannot be ruled out because children seeking music lessons might have inherently higher levels of executive functions and/or intelligence. Although music lessons might enhance executive functions, which in turn might improve IQ, it is also possible that higher IQ leads children to have superior executive functions, which then prepares them to persist in music lessons. Another limitation of the study is the failure to counterbalance the order of the tests of executive function. Nevertheless, tests of the most important mediating executive functions, selective attention and inhibition, were evenly distributed across the sequence of five tests, with the measure of selective attention administered second and the measure of inhibition administered fourth.

Our finding that music lessons were related to executive functions also contributes to the debate about whether music lessons are related to specific aspects of cognitive abilities (e.g., language) or to general aspects (e.g., intelligence). The positive association between executive functions and performance on different cognitive tasks might not only underlie the general link, but also the observed associations between music lessons and specific cognitive abilities. For example, the link between music and language abilities might be mediated by executive functions (Moreno, 2009). This claim is supported by findings that executive functions are heightened in musicians as well as in bilinguals (Bialystok & DePape, 2009), as well as by reports of superior verbal-memory performance in musically trained compared to untrained adults and children (Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003). The possible mediating role of executive functions in reported associations between music lessons and specific cognitive abilities could be examined in future research.

In summary, the results of the present study indicate that music lessons are related to executive functions and that the association between music lessons and intelligence is mediated by executive functions, in particular, by selective attention and inhibition. Further research could examine the possibility of similar mediating effects in an experimental context, and evaluate the role of executive functions in explaining links between music lessons and more specific aspects of cognition.

Author Note

Franziska Degé, Claudia Kubicek, and Gudrun Schwarzer, Department of Developmental Psychology, Justus-Liebig-University.

This research was supported by the Graduate School for Neuronal Representation and Action Control (NeuroAct) of the University of Gießen and the University of Marburg. The authors thank the Liebigschule and the Ostschule in Gießen for their cooperation as well as the children and parents who participated in the study. The authors also thank J. H. Fuhr Spiel Freizeit Hobby for the donation of gift certificates, and Ellen Winner and Glenn Schellenberg for comments on earlier drafts of this manuscript.

Correspondence concerning this article should be addressed to Franziska Degé, Department of Developmental Psychology, Otto-Behaghel-Str. 10F, Justus-Liebig-University 35394 Gießen, Germany. E-mail: franziska.dege@psychol.uni-giessen.de

References

Ardila, A., Pineda, D., & Rosselli, M. (2000). Correlation between intelligence test scores and executive function measures. *Archives of Clinical Neuropsychology, 15*(1), 31–36.

Bialystok, E., & DePape, A. M. (2009). Musical expertise, bilingualism, and executive functioning. *Journal of Experimental Psychology-Human Perception and Performance, 35*(2), 565–574.

Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *Behavioral and Brain Sciences, 29*(2), 109–160.

Brandler, S., & Rammsayer, T. H. (2003). Differences in mental abilities between musicians and non-musicians. *Psychology of Music, 31*, 123–138.

Bugos, J. A., Perlstein, W. M., McCrae, C. S., Brophy, T. S., & Bedenbaugh, P. H. (2007a). Individualized piano instruction enhances executive functioning and working memory in older adults. *Aging and Mental Health, 11*, 464–471.

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

CHEEK, J. M., & SMITH, L. R. (1999). Music training and mathematics achievement. *Adolescence, 34*(136), 759–761.

DEGÉ, F., WEHRUM, S., STARK, R., & SCHWARZER, G. (2011). The influence of two years of school music training in secondary school on visual and auditory memory. *European Journal of Developmental Psychology*, *8*, 608–623.

GARON, N., BRYSON, S. E., & SMITH, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31–60.

GRUHN, W., GALLEY, N., & KLUTH, C. (2003). Do mental speed and musical abilities interact? *Neurosciences and Music, 999*, 485–496.

HANNON, E. E., & TRAINOR, L. J. (2007). Music acquisition: Effects of enculturation and formal training on development. *Trends in Cognitive Sciences, 11*, 466–470.

HELMBOLD, N., RAMMSAYER, T. H., & ALTENMULLER, E. (2005). Differences in primary mental abilities between musicians and nonmusicians. *Journal of Individual Differences, 26*, 74–85.

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.

JÄNCKE, L. (2009). Planung, Handlung und Selbstkontrolle. Der Frontalkortex und die Musik [Planning, action, and self-control. The frontal cortex and music]. In Bundesministerium für Bildung und Forschung (Ed.), *Pauken mit Trompeten* (pp. 88–97). Bonn, Berlin: Bundesministerium für Bildung und Forschung.

KORKMAN, M., KIRK, U., & KEMP, S. (2007). *A developmental neuropsychological assessment; NEPSY-II*. San Antonio, TX: Harcourt Assessment, Inc.

MIYAKE, A., FRIEDMAN, N. P., EMERSON, M. J., WITZKI, A. H., HOWERTER, A., & WAGER, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100.

MORENO, S. (2009). Can music influence language and cognition? *Contemporary Music Review, 28*, 329–345.

MORENO, S., MARQUES, C., SANTOS, A., SANTOS, M., CASTRO, S. L., & BESSON, M. (2009). Musical training influences linguistic abilities in 8-year-old children: More evidence for brain plasticity. *Cerebral Cortex, 19*, 712–723.

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

RAUSCHER, F. H., SHAW, G. L., & KY, K. N. (1993). Music and spatial task performance. *Nature, 365*, 611–611.

RAUSCHER, F. H., SHAW, G. L., LEVINE, L. J., WRIGHT, E. L., DENNIS, W. R., & NEWCOMB, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. *Neurological Research, 19*, 2–8.

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

SCHELLENBERG, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology, 98*, 457–468.

SCHELLENBERG, E. G. (2011). Examining the association between music lessons and intelligence. *British Journal of Psychology, 102*, 283–302.

SCHELLENBERG, E. G., & MORENO, S. (2010). Music lessons, pitch processing, and g. *Psychology of Music, 38*, 209–221.

SCHELLENBERG, E. G., & PERETZ, I. (2008). Music, language and cognition: unresolved issues. *Trends in Cognitive Sciences, 12*, 45–46.

SCOTT, L. (1992). Attention and perseverance behaviours of preschool-children enrolled in suzuki violin lessons and other activities. *Journal of Research in Music Education, 40*, 225–235.

THOMPSON, W. F., SCHELLENBERG, E. G., & HUSAIN, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science, 12*, 248–251.

WECHSLER, D. (1991). *Wechsler Intelligence Scale for Children - Third Edition*. San Antonio, TX: Psychological Corporation.

WECHSLER, D. (1997). *Wechsler Adult Intelligence Scale- Third Edition*. San Antonio, TX: Psychological Corporation.

WECHSLER, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: Psychological Corporation.

WEISS, R. H. (2006). *CFT 20-R Grundintelligenztest Skala 2*. Göttingen: Hogrefe.

ZELAZO, P. D., CARLSON, S. M., & KESEK, A. (2008). The development of executive function in childhood. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (2nd ed., pp. 553–574). Cambridge, MA: MIT Press.