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RESEARCH REPORT

Explaining the Association Between Music Training and Reading in Adults

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We sought to clarify whether the positive association between music lessons and reading ability is explained better by shared resources for processing pitch and temporal information, or by general cognitive abilities. Participants were native and nonnative speakers of English with varying levels of music training. We measured reading ability (comprehension and speed), music-perception skills (melody and rhythm), general cognitive ability (nonverbal intelligence, short-term memory, and working memory), and socioeconomic status (SES; family income, parents' education). Reading ability was associated positively with music training, English as a native language, and general cognitive ability. The association between reading and music training was significant after SES, native language, and music-perception skills were controlled. After general cognitive abilities were held constant, however, there was no longer an association between reading and music training. These findings suggest that the association between reading ability and music training is a consequence of general cognitive abilities.

Keywords: music, reading, training, rhythm, working memory

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Music and spoken language involve temporal patterns of sounds that convey information. Both domains could, therefore, draw on the same mental resources. In line with this view, researchers have attempted to understand whether musical skills are associated positively with language skills, and whether training in music improves language abilities. Reviews of correlational evidence confirm that musically trained individuals often outperform their untrained counterparts on a range of language tasks, including those that measure reading (Schellenberg & Weiss, 2013; Swaminathan & Schellenberg, 2014).

The association between music training and reading is particularly interesting because reading is a seemingly *visual* process. In childhood, longer durations of music training predict better reading abilities in some instances (Corrigall & Trainor, 2011). In other instances, however, null findings emerge (Banai & Ahissar, 2013; Swaminathan & Gopinath, 2013). A meta-analysis from several years ago concluded that there is a significant relation between music lessons and reading, but found little evidence for a causal link (Butzlaff, 2000). Thus, it remains unclear why music training is associated with reading, and whether the correlation reflects a causal role for music lessons, as some scholars suggest (e.g., Tierney & Kraus, 2013). In the present study, we considered possible explanatory mechanisms, including music-perception skills and general cognitive ability.

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Music Perception as an Explanatory Factor

The association between music training and reading ability may be mediated by basic auditory skills, including those that are relevant for music perception, which tend to be enhanced among individuals with formal training (Schellenberg & Weiss, 2013). Reading involves linking visual symbols (letters and words) with the sounds of speech. Musically trained individuals have superior processing of phonemic contrasts (Kraus & Chandrasekaran, 2010) and better phonological awareness (i.e., knowledge of potentially meaningful speech sounds; Degé & Schwarzer, 2011). Such speech-perception skills are essential for the development of reading. For example, the core deficiency in developmental dyslexia appears to be one of phonology, such that individuals have trouble identifying and manipulating component sounds within words (Ziegler & Goswami, 2005).

Tallal and Gaab (2006) propose that dyslexia stems from a basic auditory deficit in rapid *temporal* processing, which Goswami (2011) extends to longer time scales. In her view, phonological development scaffolds on the prosodic regularities and the rhythmic context of speech, in which the amplitude envelope marks changes in intensity over time. Accordingly, individuals with dyslexia have impaired perception of amplitude rise time (Goswami et al., 2002), and of slower changes marked by syllable stress and speech rhythm (e.g., Leong, Hämäläinen, Soltész, & Goswami, 2011). They also exhibit deficits in musical rhythm skills (Goswami, Huss, Mead, Fosker, & Verney, 2013; Huss, Verney, Fosker, Mead, & Goswami, 2011). Moreover, impairments in rhythm perception predict later deficits in reading achievement (Goswami et al., 2013), and rhythm-based training improves phonological skills in dyslexia (Flaugnacco et al., 2015; Thomson, Leong, & Goswami, 2013).

Even among typically developing individuals, rhythm perception predicts reading or the phonological abilities that are crucial for learning to read (Anvari, Trainor, Woodside, & Levy, 2002; Banai & Ahissar, 2013; Dellatolas, Watier, Le Normand, Lubart, & Chevrie-Muller, 2009; Grube, Kumar, Cooper, Turton, & Griffiths, 2012; Moritz, Yampolsky, Papadelis, Thomson, & Wolf, 2013; Tierney & Kraus, 2013). Nevertheless, there is also evidence from typically developing children for associations between *pitch* perception and phonological awareness or reading skills (Grube et al., 2012; Loui, Kroog, Zuk, Winner, & Schlaug, 2011). In fact, musical pitch perception is sometimes better than rhythm perception at predicting phonological abilities and reading skills (Anvari et al., 2002). It remains unclear, therefore, whether the association between music training and reading can be predicted by music-perception skills, and whether rhythm perception is a better predictor of reading than pitch perception.

Recent findings indicate that individual differences in music-perception skills predict nonverbal intelligence better than music training does (Swaminathan, Schellenberg, & Khalil, 2017). If music-perception abilities are similarly implicated in the link between music training and reading, at least two explanatory models are possible. Music lessons could improve basic listening skills, including those required for music perception, which ultimately improve reading skills (Figure 1, Model A). Alternatively, preexisting differences in listening skills could influence reading ability and the likelihood of taking music lessons (Figure 1, Model B).

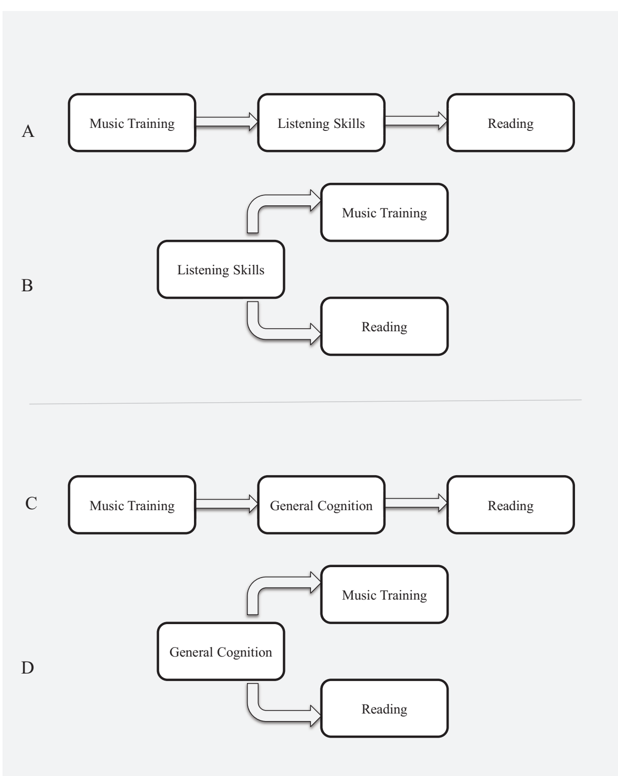

Figure 1. Possible explanations of the association between music lessons and reading include listening skills (A and B) and general cognitive skills (C and D). Music lessons may improve reading skills by improving listening skills, including those used in music perception, or general cognition (A and C). Alternatively, preexisting music-perception skills or general cognition could predict reading and the decision to take music lessons (B and D).

General Cognition as an Explanatory Factor

Music lessons are associated with general cognitive abilities, including general intelligence, working memory, and executive functions, which are crucial for reading (e.g., Daneman & Carpenter, 1980; Long, Johns, & Morris, 2006; Van Dyke, Johns, & Kukona, 2014). Indeed, musically trained individuals outperform their untrained counterparts on IQ tests (e.g., Gibson, Folley, & Park, 2009; Schellenberg, 2011a, 2011b; Schellenberg & Mankarious, 2012), as well as on auditory and visual tests that measure working or STM (Degé, Wehrum, Stark, & Schwarzer, 2011; Schellenberg, 2011a) and executive functions (Degé, Kubicek, & Schwarzer, 2011; Roden, Grube, Bongard, & Kreutz, 2014; Slevc, Davey, Buschkuehl, & Jaeggi, 2016). Thus, music lessons may enhance general cognitive skills (e.g., Schellenberg, 2004), which, in turn, promote linguistic accomplishment (Figure 1, Model C). Alternatively, associations between music training and reading may emerge because high-functioning individuals tend to take music lessons and perform well on tasks that assess language skills (Figure 1, Model D). Either way, the association between music lessons and reading would be just one example of the link between music training and general cognitive abilities.

The Present Study

Studies of associations between music lessons and reading have typically examined samples of children and adolescents who do not yet read with adultlike proficiency (e.g., Butzlaff, 2000; Corrigall & Trainor, 2011). In the present investigation, we sought to replicate the association in adults, and to examine whether it is better attributed to pitch and temporal processing or to general cognitive abilities. Because theories of temporal overlap between music and language suggest that rhythm perception is particularly important during language *acquisition*, they may be relevant primarily for adults reading a language they have not yet mastered completely. Thus, we examined associations between music lessons and English-reading ability in native and nonnative speakers of English, which also ensured that our sample had a wide range of reading ability.

Method

This study was approved by the Research Ethics Board at the University of Toronto.

Participants

The participants were 166 undergraduates (120 women, mean age = 19.3 years, *SD* = 2.4) attending a midsize Canadian university where the language of instruction was English.[1] None had a history of speech, language, or hearing problems (self-reports). One additional participant was tested but excluded be-

[1] Nonnative speakers need to provide evidence of proficiency in English in order to enroll at the University of Toronto Mississauga. Specifically, they need a Test of English as a Foreign Language (TOEFL) score of 100 with 23 on writing, or an International English Language Testing System (IELTS) score of 6.5 with 6.0 on each band.

cause of a history of stuttering. Recruitment was limited to students who were clearly native or nonnative speakers of English. The native speakers ($n = 74$, 54 women) lived in Canada from 5 years of age (or earlier) and received all of their formal education in English. The nonnative speakers ($n = 92$, 66 women) were born in a non-English-speaking country and educated in a foreign language until at least age 14. They spoke a foreign language at home (see online supplemental materials) and lived in Canada for no more than 4 years. Fifty spoke a tone language. The others spoke one of 13 nontonal languages.

On average, participants had 2.0 years of private music lessons taken outside of school, but the distribution was skewed positively ($SD = 4.2$). For participants who reported learning more than one instrument (or voice), duration of music training was summed across instruments as in previous research (e.g., Corrigall, Schellenberg, & Misura, 2013; Schellenberg, 2006). We also considered music lessons taught in schools because of the possibility of marked cultural differences in this regard, and the distribution was skewed similarly ($M = 3.0$, $SD = 4.2$, median = 1, mode = 0). We tried various ways of coding and combining the measures of music training for use in the analyses that follow. Regardless, the findings did not change. Here, music training was considered as the combined duration of school and private music lessons, square-root transformed. Results from alternative methods of coding music training are reported in the online supplemental materials.

Measures.

SES. Because duration of music training and intelligence are often associated positively with SES (e.g., Schellenberg, 2006), participants provided information about their family income and their parents' education. Annual family income was measured on a scale ranging from 1 (<$25,000) to 9 (>$200,000), with a unit increase representing an increment of $25,000. For both parents, the highest level of education was recorded on a scale ranging from 1 (*did not complete high school*) to 8 (*graduate degree*). Because mothers' education and fathers' education were correlated, $r = .56$, $p < .001$, the variables were averaged. For participants with missing data (family income: $n = 7$, parents' education: $n = 2$), the mean was substituted.

General cognitive abilities. Verbal short-term and working memory were measured with the Digit Span subtest from the Wechsler Adult Intelligence Scale (Wechsler, 2008). Raw scores (total number of correct trials) for forward and backward spans were considered separately as measures of short-term and working memory, respectively. Nonverbal intelligence was measured with the abbreviated 12-item version of Raven's Advanced Progressive Matrices, developed by Bors and Stokes (1998). Participants were given 10 min to complete the test and their score was the total number of correct responses.

Music perception. The Musical Ear Test (MET; Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010a, 2010b) was used to test musical competence. Although the MET is described by the authors as a test of musical *competence*, it is similar to music aptitude tests that have been used over the past century (e.g., Seashore, 1919; Seashore, Saetveit, & Lewis, 1960). It required participants to make 104 same-different judgments. The Melody subtest, administered first, required comparison of two piano melodies on each of 52 trials. On 26 "different" trials, one tone was displaced in pitch. The Rhythm subtest, also with 52 trials, required comparison of two wood-block rhythms. On 26 different trials, one beat was displaced in time. Scores on the Melody and Rhythm subtests were the total number of correct responses.

The MET has good internal reliability (Wallentin et al., 2010b). Its validity is documented by showing that performance is highest among professional musicians, intermediate among amateur musicians, and lowest among nonmusicans (Wallentin et al., 2010a). Scores are also correlated positively with amount of playing (or practice) per week, performance on a musical reproduction task, and verbal STM, but not with spatial short-term or working memory (Hansen, Wallentin, & Vuust, 2013; Wallentin et al., 2010a). The MET has been used frequently in studies of associations with nonmusical abilities (e.g., Bhatara, Yeung, & Nazzi 2015; Slevc et al., 2016; Swaminathan & Schellenberg, 2017; Swaminathan et al., 2017), perhaps because other recent tests of music-listening skills are longer (Law & Zentner, 2012), designed for special populations (Peretz, Champod, & Hyde, 2003), or reliant on self-reports (Müllensiefen, Gingras, Musil, & Stewart, 2014).

Reading ability. Reading comprehension was measured with the Comprehension subtest from the Nelson-Denny test of reading ability (Brown, Fishco, & Hanna, 1993). This 20-min subtest consisted of seven reading passages and a total of 38 questions that measured participants' understanding of what they read. Raw scores were converted to standardized scores. Most participants used the maximum amount of time. A second, dummy variable representing reading speed was coded 1 for other participants ("fast" readers, $n = 51$) and 0 for the majority ("slow" readers, $n = 115$).

Data reduction. To reduce collinearity among predictor variables and to minimize the contribution of measure-specific error variance, aggregate variables were formed separately for SES, general cognitive ability, and reading ability. In each instance, measured variables were converted to z scores and averaged. This method was mathematically equivalent ($r = 1$) to extracting the principal component from two measured variables (SES, reading ability), and nearly equivalent ($r = .98$) from three (general cognitive ability). In each instance, the measured variables were correlated highly with the aggregate variable (SES: parent's education and family income, rs = .76; general cognitive ability: STM, $r = .69$, working memory, $r = .78$, nonverbal intelligence, $r = .60$; reading ability: reading comprehension and reading speed, rs = .85).

Procedure

Participants were tested individually in a quiet room. They completed the digit-span test, followed by the reading test and a questionnaire that asked for background information (history of music training, demographics). After a short break, they completed the test of nonverbal intelligence and finally the MET. The entire testing session took approximately 75 min.

Results

Overarching goals of the analyses were first to confirm that music training was associated with reading ability among native and nonnative speakers of English, and then to determine whether music perception—particularly rhythm perception—could explain the association, or, alternatively, whether the association was better explained by general cognitive ability.

Preliminary tests of associations among demographic variables (age, gender, SES, native language) revealed that men tended to come from higher SES families than women, $t(164) = 2.35$, $p = .020$, and that native speakers of English tended to be younger than other participants, $t(164) = 5.59$, $p < .001$. Correlations between demographic and other study variables are provided in Table 1. (Because the goal was to identify possible confounding variables, we adopted a liberal criterion, $\alpha < .1$.) Younger participants were more likely to have studied music for longer durations, and to have marginally lower levels of reading ability. Males had marginally higher reading scores and marginally lower rhythm perception scores than females. SES was associated positively with music training and rhythm perception, and marginally so with general cognition. Compared to native speakers of English, nonnative speakers had lower reading-ability scores and fewer years of music training, but higher levels of general cognitive ability. Nonnative speakers also had *better* melody perception. As illustrated in Figure 2, the melody advantage emerged because speakers of a tone language outperformed native speakers of English, $p < .001$, as well as other nonnative speakers, $p = .020$. Performance did not differ between native speakers of English and other nonnative speakers, $p > .2$.

Correlations among study variables are provided in Table 2. In general, the variables were associated positively, as expected, except for rhythm perception, which was correlated significantly only with melody perception and general cognition. Another exception was that melody perception was not associated with reading ability. In other words, pitch and temporal processing skills, as measured by the MET, had no association with reading. Nevertheless, music training had positive associations with reading ability, general cognitive ability, and melody perception.

Although rhythm perception was *not* correlated with reading ability or with music training, we conducted additional tests because of its theoretical importance. Specifically, we held native language constant and ran tests of partial association. Rhythm perception remained uncorrelated with music training, $p = .098$, and reading ability, $p > .8$. We also tested whether associations varied between our native and nonnative speakers by creating a variable representing the interaction of native language with rhythm perception (after centering the main effects). We then predicted music training and reading ability and as a function of rhythm perception, native language, and the interaction between rhythm perception and native language. The interaction was not significant for music training, $p > .3$, or for reading ability, $p > .9$. In short, there was no evidence that rhythm perception was associated with music training or reading ability, or that it played a role in the link between music training and reading among native and nonnative speakers of English.

In the principal analysis, hierarchical multiple regression was used to predict reading ability. Statistical results are reported in Table 3. On the first step, predictors were demographic variables (age, gender, SES, native language) and music training. The regression model was significant but only native language and music training made significant independent contributions. On the second step, we added melody and rhythm perception, which did not significantly improve the model. At this step, better reading ability was still predicted independently by music training and native language. Thus, music training was associated positively with reading when age, gender, SES, native language, melody perception, and rhythm perception were held constant. On the third and final step, we added general cognitive abilities, which significantly improved the fit of the model. Native language and general cognition were independent predictors of reading ability; the contribution of music training fell short of statistical significance, $p = .087$.[2]

A final analysis sought to determine whether the link between music training and reading ability was mediated by general cognitive abilities (Baron & Kenny, 1986; Sobel, 1982). If so, the results would still be consistent with the notion of a causal (but mediated) effect from music training to reading. After controlling for demographics, native language, and music perception, Sobel's test of mediation was not significant, $p > .1$. Moreover, a bootstrap estimation approach (Preacher & Hayes, 2004) with 50,000 samples provided a 95% confidence interval for the size of the indirect effect, which contained 0. Thus, there was no evidence that music training improved reading ability by enhancing general cognitive abilities.

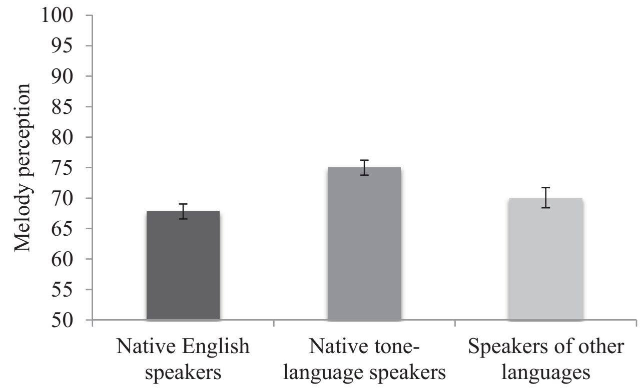

Figure 2. Average performance on the melody-perception task as a function of native language. Scores are percentages. Error bars are standard errors. Chance responding is 50% correct.

Table 1
Pairwise Correlations Between Study Variables and Demographic Variables

Variable	Age	Gender	SES	Native language
General cognition	.08	.11	.15*	−.17**
Melody perception	−.02	−.01	.12	−.24***
Rhythm perception	−.01	−.15*	.15**	−.04
Music training	−.18**	.09	.23***	.20**
Reading ability	−.14*	.15*	.10	.41***

Note. Gender (0 = female, 1 = male) and native language (0 = other, 1 = English) were dummy variables. SES = socioeconomic status.
* $p < .1$. ** $p < .05$. *** $p < .01$.

[2] We also compared individuals with no music lessons ($n = 55$) to those with at least 9 years ($n = 34$). Although the simple association between music training and reading was significant, $p = .001$, the partial association (i.e., on the final step of the hierarchical regression) was not, $p = .170$.

Table 2
Pairwise Correlations Among Study Variables

Variable	Melody perception	Rhythm perception	Music training	Reading ability
General cognition	.28**	.24**	.18*	.21**
Melody perception		.41**	.26**	−.05
Rhythm perception			.12	−.03
Music training				.26**

* $p < .05$. ** $p < .01$.

Discussion

As in previous research with children and adolescents, music training and reading ability were associated positively among adults in the present study. The association remained evident after controlling for demographic variables (including native language) and music-perception skills. It became nonsignificant, however, when general cognitive abilities were held constant. Perhaps associations with music training are evident only when lower-level aspects of reading ability are tested (e.g., phonological awareness, nonword reading).

In contrast to results from studies of children (e.g., Goswami et al., 2013; Loui et al., 2011), we found no association between music-perception skills and reading ability in adult native and nonnative speakers of English. Perhaps even more surprising was the finding that rhythm perception was not correlated with music training, which contrasts with findings from other researchers, who administered the MET to smaller samples (*N*s < 150) of American (Slevc et al., 2016), Danish (Hansen et al., 2013; Wallentin et al., 2010a), and French (Bhatara et al., 2015) adults. Our null finding is difficult to explain but could stem from our multicultural sample, or from pedagogical differences in music training between Canada and elsewhere. In any event, music-perception skills, and particularly rhythm perception, did not mediate the association between music training and reading skills, contrary to predictions from theories of auditory temporal overlap. It is nevertheless possible that overlap between music and language skills is more likely in children than in adults, for whom linguistic and musical cognition may have become independent processes (McMullen & Saffran, 2004). Another possibility is that an association between temporal processing and reading could emerge if a test other than the MET were administered. In the study by Bhatara et al. (2015), rhythm scores from the MET were correlated positively with the number of foreign-language courses participants had taken.

In line with the literature, general cognitive abilities were associated with reading skills (e.g., Long et al., 2006; Van Dyke et al., 2014) and with music training (Schellenberg, 2006, 2011a). And, as expected, native speakers of English outperformed nonnative speakers in reading ability. In other words, our test of reading ability appeared to be valid. The nonnative speakers also performed better on the test of melody perception. Specifically, tone-language speakers outperformed other nonnative speakers of English as well as native speakers. This result is consistent with past studies that documented pitch-perception advantages in tone-language speakers relative to monolingual English speakers (Bidelman, Hutka, & Moreno, 2013; Creel, Weng, Fu, Heyman, & Lee, 2017; Pfordresher & Brown, 2009), and suggests that linguistic experience can, in fact, modify musical abilities when the perceptual and cognitive demands of the language are relevant to the musical skill being tested.

Because the association between music training and reading was marginally significant after controlling for demographics, music perception, and general cognition, the issue of statistical power needs to be raised. With a larger sample, music lessons may indeed have a significant partial association with reading. Power analysis conducted with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) confirmed that we had more than an 80% chance of detecting a partial association that accounted for 5% of the variance in reading ability on the final step of the hierarchical regression (see Table 3). Thus, if music training does indeed have a significant partial association with reading ability in the general population, the present findings suggest that such an association is small.

Rather, the association between music training and reading appears to be a consequence of individual differences in general cognition. In principle, this result could represent a training effect,

Table 3
Hierarchical Multiple Regression Predicting Reading Ability

Variable	Step 1		Step 2		Step 3	
	pr	*p*	*pr*	*p*	*pr*	*p*
Age	.072	.360	.073	.360	.055	.492
Gender	.149	.059	.141	.076	.112	.159
SES	.057	.468	.061	.440	.046	.563
Native language	.385**	<.001	.368**	<.001	.404**	<.001
Music training	.175*	.026	.168*	.034	.136	.087
Melody perception			.010	.905	−.026	.747
Rhythm perception			−.031	.698	−.076	.341
General cognition					.272**	.001
R	.474		.475		.532	
R^2	.225		.226		.283	
Adjusted R^2	.201		.191		.247	
F	9.280**	<.001	6.574**	<.001	7.748**	<.001
ΔF			.076	.926	12.590**	.001

Note. *pr* = partial correlation; SES = socioeconomic status.
* $p \leq .05$. ** $p \leq .001$.

such that music lessons enhance general cognitive abilities (e.g., Schellenberg, 2004), which translate to better reading. In fact, studies of music training and nonmusical abilities tend to interpret positive correlations as evidence for behavioral and brain plasticity induced by music training (e.g., Kraus & Chandrasekaran, 2010). Although our mediation analyses found no evidence for such a training effect, further research with designs that maximize power to detect mediating variables is needed to make definitive conclusions. In our view, however, a more likely possibility is that music lessons are the consequence rather than the cause of better cognitive performance. In other words, preexisting cognitive advantages lead to better reading performance and an increased likelihood of taking music lessons. Our interpretation is consistent with findings showing that (a) early school achievement predicts musical enrolment in subsequent years (Kinney, 2008, 2010), and (b) common genetic factors explain cognitive abilities, musical skills, and the propensity to practice music (Mosing, Madison, Pedersen, & Ullén, 2016; Mosing, Pedersen, Madison, & Ullén, 2014).

In any event, the choice between radical environmentalism and biological determinism is a false dichotomy. A more complicated explanation, illustrated in Figure 3, is one of a gene-environment interaction (Schellenberg, 2015). High-functioning individuals may be more inclined to participate in music lessons, which then go on to strengthen preexisting cognitive proclivities. In other words, both nature and nurture are likely to be implicated in the associations among music lessons, general cognition, and reading that we observed.

In sum, our findings provide evidence that the association between music training and reading in adults is the consequence, in part or in full, of better general cognitive ability, but not of better music-perception skills. Future experimental work that randomly assigns participants to music training and control interventions, *and* considers the role of preexisting individual differences (e.g., in cognitive abilities, music aptitude, and personality; Butkovic, Ullén, & Mosing, 2015; Corrigall et al., 2013) is needed to understand fully why musically trained individuals perform well on tests of reading ability and many other cognitive abilities.

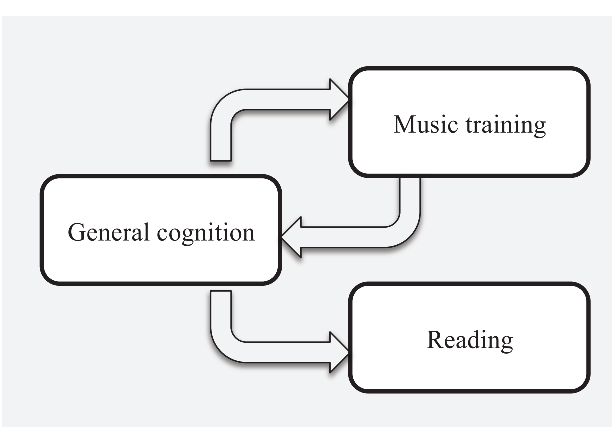

Figure 3. Beyond nature versus nurture: Music training could both cause and be caused by better general cognition, which, in turn, determines reading ability.

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