American Psychological Association

Journal of Experimental Psychology:
Learning, Memory, and Cognition

ISSN: 0278-7393

2020, Vol. 46, No. 12, 2340–2348
http://dx.doi.org/10.1037/xlm0000798

Musical Ability, Music Training, and Language Ability in Childhood

Swathi Swaminathan
University of Toronto

E. Glenn Schellenberg
University of Toronto Mississauga

We tested theories of links between musical expertise and language ability in a sample of 6- to 9-year-old children. Language ability was measured with tests of speech perception and grammar. Musical expertise was measured with a test of musical ability that had 3 subtests (melody discrimination, rhythm discrimination, and long-term memory for music) and as duration of music training. Covariates included measures of demographics, general cognitive ability (IQ, working memory), and personality (openness-to-experience). Music training was associated positively with performance on the grammar test, musical ability, IQ, openness, and age. Musical ability predicted performance on the tests of speech perception *and* grammar, as well as IQ, working memory, openness, and age. Regression analyses—with other variables held constant—revealed that language abilities had significant partial associations with musical ability and IQ but not with music training. Rhythm discrimination was a better predictor of language skills compared with melody discrimination, but memory for music was equally good. Bayesian analyses confirmed the results from the standard analyses. The implications of the findings are threefold: (a) musical ability predicts language ability, and the association is independent of IQ and other confounding variables; (b) links between music and language appear to arise primarily from preexisting factors and not from formal training in music; and (c) evidence for a special link between rhythm and language may emerge only when rhythm discrimination is compared with melody discrimination.

Keywords: music, rhythm, language, speech, grammar

Supplemental materials: http://dx.doi.org/10.1037/xlm0000798.supp

In the present investigation, we sought to test theories and models of associations between musical expertise and language ability. One theory, Patel's (2011, 2014) OPERA hypothesis, proposes that formal training in music leads to benefits in speech perception and language processing because neural networks for music and speech processing **O**verlap, music requires **P**recision in auditory processing, music elicits positive **E**motions, music training involves **R**epetition that facilitates learning, and music learning requires **A**ttention. In other words, Patel posits a transfer effect from music to language that is driven by an overlap in goals (communication) and modality (audition) but enhanced by specific aspects of the music-learning process. Kraus (Kraus & Chandrasekaran, 2010; Kraus & Nicol, 2018) describes a similar view, claiming that sound encoding at the brainstem level becomes more precise with formal music training, which enhances the perception of speech sounds. Patel and Kraus both propose that initial consequences of music training are perceptual but with cascading effects that extend to higher-level language processes such as reading (e.g., Patel & Iversen, 2007; Tierney & Kraus, 2013). Thus, *any* positive association between music training and language ability is consistent with their view.

Such associations are indeed plentiful in correlational and quasi-experimental (or cross-sectional) research (e.g., Loui, Raine, Chaddock-Heyman, Kramer, & Hillman, 2019; Swaminathan & Gopinath, 2013; for review, see Schellenberg & Weiss, 2013). Nevertheless, the theories propose a causal direction (music training → language), and these correlations are also consistent with an alternative view: High general cognitive ability includes good language *and* musical abilities (Carroll, 1993), which increase the likelihood of taking music lessons. Indeed, convincing evidence that music training *causes* improvements in language abilities is scarce (for review, see Swaminathan & Schellenberg, 2018a).

Other evidence indicates that *rhythm* abilities in particular (e.g., Corriveau & Goswami, 2009) are closely linked with language skills. The underlying theory (Goswami, 2011; Tallal & Gaab, 2006) proposes that children with reading or language problems (i.e., dyslexia or specific language impairment [SLI]) have a temporal-processing deficit that impairs processing of rise time and duration in speech (Corriveau, Pasquini, & Goswami, 2007),

---

Swathi Swaminathan, Department of Psychology, University of Toronto; E. Glenn Schellenberg, Department of Psychology, University of Toronto Mississauga.

Swathi Swaminathan is now at the Department of Neuropsychology and Cognitive Health, and Rotman Research Institute, Baycrest Health Sciences, Toronto, Canada.

Funding provided by the Natural Sciences and Engineering Research Council of Canada. Laura Cirelli and Haley Kragness provided helpful comments on a draft.

The data that support the findings of this study are available from E. Glenn Schellenberg (g.schellenberg@utoronto.ca) upon reasonable request.

Correspondence concerning this article should be addressed to E. Glenn Schellenberg, Department of Psychology, University of Toronto Mississauga, Mississauga, ON L5L 1C6, Canada. E-mail: g.schellenberg@utoronto.ca

which is crucial for the perception of rhythm and prosody (particularly amplitude changes) and, ultimately, phonological representation (Goswami, 2011; Port, 2007). This deficit should therefore be ameliorated by music training that improves rhythm skills. Because the deficit does not extend to the perception of frequency (pitch), rhythm abilities should predict language skills, but other aspects of musical ability, such as melody discrimination, should not. Indeed, rhythm but not melody discrimination predicts (a) the perception of stress in speech among Finnish adults (Hausen, Torppa, Salmela, Vainio, & Särkämö, 2013), (b) foreign-language learning among French adults (Bhatara, Yeung, & Nazzi, 2015), and (c) the categorization of Zulu phonemes among Canadian adults (Swaminathan & Schellenberg, 2017). Nevertheless, in one intervention study with 4- to 6-year-olds, training that focused on melody (pitch relations) improved phonological awareness, but training in rhythm did not (Patscheke, Degé, & Schwarzer, 2019). In any event, comparisons of rhythm with melody (and *only* melody) do not provide adequate tests of the hypothesis that rhythm has a "special" link with language. Other aspects of musical ability could be equally important.

A final perspective posits an association between rhythm and *grammatical* abilities (Gordon, Jacobs, Schuele, & McAuley, 2015; Gordon, Shivers, et al., 2015), based on observed deficits in rhythm and grammar that are evident in SLI and on findings showing that (a) temporal cues mark phrase boundaries (e.g., Fernald & McRoberts, 1996) and important words (e.g., Rothermich, Schmidt-Kassow, & Kotz, 2012) in speech, and (b) speech rhythms influence syntactic processing (e.g., Roncaglia-Denissen, Schmidt-Kassow, & Kotz, 2013). Supporting evidence comes from a study of typically developing 6-year-old American children (Gordon, Shivers, et al., 2015), whose ability to detect changes in rhythmic sequences was positively correlated with grammar abilities but *not* with phonological awareness. The sample size was small, however, so the finding is inconclusive, particularly because links between music training and phonological awareness are well established (for review, see Gordon, Fehd, & McCandliss, 2015). Moreover, there was no control test (melody or otherwise) to provide discriminant validity. In one study of 3- and 4-year-olds, rhythm abilities predicted phonological awareness, but *melody* perception predicted grammar (Politimou, Dalla Bella, Farrugia, & Franco, 2019).

Regardless, for all of these theories, predicted associations between music and language should be evident when potential confounding variables (demographics, general cognitive ability, personality) are held constant. More specifically, according to Patel and Kraus, music *training* should be associated with a variety of language abilities, particularly speech perception. According to Goswami or Gordon, *rhythm ability* should be correlated positively with speech perception or grammar, respectively.

To test these predictions, we recruited a sample of Canadian children 6 to 9 years of age, for whom language and musical abilities are still developing rapidly and therefore particularly plastic and amenable to training, and because younger children would be less likely to have received formal music lessons. We were skeptical about hypothesized associations between music training and language ability because causal evidence is limited and because in adulthood, rhythm discrimination predicts speech perception, but music training does not (Swaminathan & Schellenberg, 2017). Moreover, associations between music training and reading comprehension disappear when general cognitive ability is held constant (Swaminathan, Schellenberg, & Venkatesan, 2018). In any case, we expected that rhythm ability would be associated with speech perception because the association is evident for adults (Swaminathan & Schellenberg, 2017) and because meta-analytical results document improvements in phonological awareness as a consequence of rhythm training (Gordon, Fehd, et al., 2015). We were less confident about finding a link between rhythm ability and grammar because of conflicting evidence (Gordon, Shivers, et al., 2015; Politimou et al., 2019).

Method

The study protocol received ethical approval from the Research Ethics Board of the University of Toronto.

Participants

Participants were 91 children (45 girls) between 6 and 9 years of age (mean [M] = 7.84 years, standard deviation [SD] = 1.19), recruited from families living in a large metropolitan area in Canada. Age (in months) was held constant in the statistical analyses. According to parent reports, fewer than half of the children were monolingual native speakers of English (n = 44), a reflection of the multicultural makeup of the local community. The other children were bilingual or multilingual (n = 47), most of whom started learning English in infancy (n = 88). The remaining three started learning English by age 4. Nineteen of the bilingual children were in French-immersion schools, having started to learn French (in addition to English) at 5 or 6 years of age. In the statistical analyses, we formed a dummy variable, bilingualism, which compared monolingual children to all others (0 = *monolingual*, 1 = *bilingual/monolingual*).

Power analysis conducted with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that a sample of at least 89 was required to have 95% probability of detecting a medium effect size (i.e., d = .30, f = .15, Cohen, 1988) for each predictor variable in a multiple-regression model that included seven to nine predictors. This power analysis considered whether each predictor would have a significant *partial* correlation with each outcome variable (i.e., with other predictors held constant).

Measures

Language ability. We measured speech perception with a modified version of an AXB discrimination task used previously with adults (Swaminathan & Schellenberg, 2017) but with fewer trials and a video-game format. Stimuli were phonemic contrasts from Zulu (Best, McRoberts, & Sithole, 1988). On each trial, three Zulu tokens (CV syllables) were presented consecutively (1-s offset-to-onset interval). The first (A) and third (B) sounds were different speech tokens. The middle sound (X) was the standard. On half of the trials, X was a nonidentical token from the same phonemic category as A, and on others from the same category as B. Children determined whether A or B was different from X.

The four conditions (C1–C4) were presented in fixed order such that they increased in difficulty as a function of dissimilarity to

English consonants (Best, McRoberts, & Goodell, 2001).[1] There were eight blocks of 10 trials each, with two blocks per condition (20 trials per condition). As expected, accuracy was highest in C1, followed in descending order by C2, C3, and C4, $ps < .001$. Because performance in C4 was not reliably better than chance ($M = 9.62$, $SD = 1.98$; chance $= 10$), we did not consider this condition further. For our measure of *speech perception*, we extracted the principal component from scores in C1, C2, and C3. It accounted for 54.0% of the variance in the measured variables and was correlated strongly with C1 and C2 ($rs > .8$) and moderately with C3 ($r = .459$).

We measured knowledge of English grammar (henceforth *grammar*) with the Test for Reception of Grammar–Version 2 (TROG; Bishop, 2003). On each trial, children matched spoken sentences to one of four pictures. The test comprised 20 blocks of five trials, with blocks presented in increasing order of difficulty. Within blocks, each trial tested understanding of a single type of grammatical construction. Children passed a block if they answered correctly on all five trials. Scores represented the total number of blocks passed.

Musical expertise. According to parent reports, children had an average of 12.40 months of music lessons taken privately or in school ($SD = 26.30$). In the statistical analyses that follow, duration of training was coded 0 for children with no training ($n = 56$), 1 for those with 2 years or less ($n = 19$), and 2 for children with more than 2 years ($n = 16$). This method of coding was selected because it maximized associations between music training and the language variables, which proved to be weak. The results did not change when other methods were used (online supplementary materials, Table S1).

Musical ability was measured with the three-subtest version of the Montreal Battery of Evaluation of Musical Abilities (MBEMA; Peretz et al., 2013), which we adapted as a video game. On each trial of the melody- and rhythm-discrimination subtests (hereafter *melody* and *rhythm*), a standard melody was presented, followed by a comparison melody (1-s offset-to-onset interval). Children decided whether the two melodies were identical. Both subtests comprised 20 trials (10 same, 10 different). On "different" trials for the melody subtest, one tone in the comparison melody was displaced in pitch. The rhythm subtest that followed had the same standard melodies as the melody subtest, but on "different" trials, the durations of two adjacent notes were switched.

The third and final subtest measured long-term *memory for music*. It also comprised 20 trials, each with a single melody. On 10 trials, standard melodies from the previous subtests were presented. The other trials had novel melodies. Participants identified whether each melody was "new" or "old."

For each subtest, scores represented the number of correct responses. Extraction of the principal component from the three subtests provided an aggregate *musical ability* score. This latent variable accounted for 69.2% of the variance in the measured variables, each of which correlated highly with the latent variable, $rs > .7$.

Socioeconomic status. Parents provided information about annual family income and education (as in Corrigall, Schellenberg, & Misura, 2013; Schellenberg, 2006). Income was measured in increments of $25,000 ranging from 1 (*<$25,000*) to 9 (*>$200,000*). Both parents' highest level of education was measured on a scale ranging from 1 (*did not complete high school*) to 8 (*graduate degree*). Missing values were substituted with the mean (mother's education: $n = 1$, father's education: $n = 3$, family income: $n = 13$), which had no effect on the strength of associations but ensured that the sample comprised the same 91 children for all analyses. A principal component (hereafter *socioeconomic status [SES]*) was extracted for statistical analysis. It explained 57.2% of the variance in the original three measures, each of which correlated highly with the latent variable, $rs > .7$.

General cognitive ability. The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) includes four subtests: Block Design, Matrix Reasoning, Vocabulary, and Similarities. A principal component (hereafter *IQ*) was extracted from the four raw subtest scores (unstandardized for age) and used in subsequent analyses. The latent variable accounted for 63.9% of the variance in the original subtests, each of which loaded substantially onto the latent variable, $rs \geq .7$. This method of measuring IQ (instead of standardized scores) meant that it improved with age, as did the other measures (except for personality and SES).

Because performance on tests of musical ability is associated positively with verbal working memory (Hansen, Wallentin, & Vuust, 2013), we also administered Digit Span. The sum of correct responses on the forward and backward subtests was our measure of *working memory*.

Personality. A parent completed the Big Five Inventory for Children (BFI; John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008). Although we administered the entire scale, we were interested only in the openness-to-experience dimension (hereafter, *openness*). The openness score was the average rating of the relevant items. (The other personality dimensions did not have significant correlations with any other variables measured in this study, with one exception that is likely to be a Type I error. See online supplemental materials, Table S2.)

Procedure

Testing was conducted over two sessions, with tests of speech perception, grammar, IQ, and working memory administered in the first session (90 min) and musical ability tested in the second session (25 min). Children were tested individually in a quiet room, with auditory stimuli presented over high-quality headphones. During the first session, a parent completed a background questionnaire that asked for information about family SES and the child's personality, language background, and history of music training.

Results

Descriptive statistics for raw scores on the tests of language and musical ability are provided in Table 1. The first analysis examined associations between musical expertise and language abilities using the aggregate measure of musical ability. Simple correlations between all pairs of variables are reported in Table 2. Because gender and SES had no theoretical importance and were not

---

[1] C1 contrasted voiceless (/ɬ/) and voiced (/ɮ/) lateral fricatives followed by /ɛ/, C2 had aspirated (/kh/) and ejective (glottalized, /k′/) velar stops followed by /a/, C3 had plosive (/b/) and implosive (/ɓ/) voiced bilabial stops paired with /u/, and C4 had voiceless unaspirated apical and lateral clicks paired with /a/.

Table 1
Descriptive Statistics (N = 91) for the Measures of Language and Musical Abilities (Raw Data)

			Musical ability (MBEMA)			
Statistic	Speech	Grammar	Melody	Rhythm	Memory	Overall
M	14.48	13.52	14.26	14.99	14.49	43.84
SD	2.39	3.63	3.13	3.43	2.81	7.85
Chance	10.00	.00	10.00	10.00	10.00	30.00
Perfect	20.00	20.00	20.00	20.00	20.00	60.00

Note. MBEMA = Montreal Battery of Evaluation of Musical Abilities. Descriptive scores for speech reflect mean performance on the C1, C2, and C3 conditions.

associated with the speech, grammar, or music variables, they were excluded from further consideration in order to reduce collinearity. Partial correlations (age and bilingualism held constant) are reported in Table 3. Many pairs of variables were significantly and positively correlated, as expected (see Table 2). When demographic variables were partialed out (see Table 3), correlations tended to be smaller, but many remained significant. Both music training and musical ability had associations with cognitive ability and personality (e.g., Corrigall et al., 2013; Swaminathan & Schellenberg, 2018b). Music training and musical ability were positively correlated, as were speech perception and grammar. Speech perception and grammar had positive partial associations with musical ability but *not* with music training. In fact, musical ability had positive partial associations with all other variables, whereas music training was associated only with musical ability and IQ.

The principal analyses examined whether language skills were associated with music variables when all other variables were held constant. For both outcome measures (speech perception and grammar), we used multiple regression, with predictor variables that indexed musical expertise (music training, musical ability), demographics (SES, bilingualism), cognition (IQ, working memory), and personality (openness).

The results for speech perception are summarized in Table 4. The model accounted for 38.9% of the variance. Better speech perception was evident among children with higher IQs and among those with higher levels of musical ability, even with all other variables held constant. Unexpectedly, openness was a significant *suppressor* variable, such that higher levels of openness predicted *poorer* performance on the test of speech perception. Suppression—when a positive simple association becomes a negative partial association—means that openness was correcting for overestimates of speech-perception performance (i.e., higher predicted than observed scores) by other variables in the model (Darlington, 1990).

Bayesian analyses confirmed that the best model of the data comprised four predictor variables: IQ, musical ability, openness, and duration of music training, but music training and openness were weighted *negatively*. The probability of the observed data was 122 × 10^2 times greater with this model than the null model (no predictors) and 9.94 times greater with this model than the full model (seven predictors).[2] Removing each of the four predictors one at a time revealed that the observed data were 299, 57.6, 3.49, or 1.42 times less likely, respectively, when IQ, musical ability, openness, or duration of music training was removed from the model. In short, there was strong evidence that speech perception was associated positively with IQ and musical ability, weak evidence for a negative association with openness, and extremely weak evidence for a negative association with music training (1 = *no association*).

The results for grammar were similar (see Table 4). The model accounted for 49.0% of the variance in performance, but only IQ and musical ability made significant independent contributions. Bayesian analyses confirmed that the observed data were 213 × 10^7 times more likely with this two-variable model than with the null model and 61.4 times more likely than with the full model. Removing IQ and musical ability separately reduced the likelihood of the observed data by factors of 193 × 10 and 127, respectively. Adding music training as a third predictor *reduced* the likelihood by a factor of 1.36. Thus, for both speech perception and grammar, the main finding was that children with higher IQs and good musical abilities tended to perform the best, even after accounting for all other variables in the model, including music training.

Subsequent analyses focused on the three subtests from the MBEMA, which were intercorrelated (melody and rhythm, $r = .532$; melody and memory for music, $r = .437$; rhythm and memory for music, $r = .640$; $ps < .001$). Simple and partial correlations with other variables are reported in Table 5. All pairs of variables had significant simple associations, but partial associations were weaker and less consistent. For example, both language measures had significant partial associations with rhythm and memory for music but not with melody.

To test whether rhythm had a *special* association with language abilities, we reran the regression analyses three times, each time substituting one of the subtests from the MBEMA for the aggregate measure (see Table 6). For speech perception, melody did not make an independent contribution to the model, but rhythm did. Nevertheless, memory for music also had a partial association with speech perception that was similar in magnitude to the association with rhythm. For grammar, the results were similar. Melody had no partial association with grammar, but rhythm and memory for music did. In this instance, the partial association with memory for music was larger in absolute magnitude than the partial association with rhythm.

In the final analyses, we included rhythm *and* memory for music as predictor variables in the regression models. Although the two predictors as a pair increased the explained variance in speech perception by 8.5%, $p = .004$, neither variable made a significant contribution to the model ($.05 < ps < .10$) because the two predictors were correlated. Similarly, for grammar, the two predictors increased the explained variance by 5.6%, $p = .012$, but independent contributions of rhythm and memory for music were both nonsignificant ($.08 < ps < .15$).

Bayesian analysis confirmed that for speech perception, the observed data were 29.3 times more likely with a model that included rhythm and memory for music in addition to IQ and

---

[2] For ease of interpretation, we report BF_{10} for comparisons of the best model to the null model, and we report BF_{01} for comparisons of the best model to other models. Thus, all Bayes factors are greater than 1, and all are reported with 3-digit accuracy. Bayesian analyses were conducted with open-source software (JASP 0.10.2; JASP Team, 2019), using its default priors. The results were robust, however, across changes in the specification of the prior or the way that music training was coded.

Table 2
Simple Associations Among Variables

Variable	Grammar	Music training	Musical ability	IQ	Working memory	Openness	Age	Gender	SES	Bilingualism
Speech perception	.485**	.144	.427**	.470**	.323**	−.066	.473**	−.009	.045	.211*
Grammar		.270**	.558**	.595**	.460**	.235*	.497**	−.163	.202	.029
Music training			.457**	.521**	.179	.223*	.377**	−.079	.000	.132
Musical ability				.486**	.502**	.298**	.496**	−.177	.034	.051
IQ					.424**	.203	.677**	.009	.185	.201
Working memory						.113	.334**	−.028	.255*	.095
Openness							.062	−.270**	.047	.021
Age								−.045	−.152	.047
Gender									.045	−.121
SES										.085

Note. SES = socioeconomic status. Gender (0 = *girls*, 1 = *boys*) and bilingualism (0 = *monolingual*, 1 = *other*) were dummy coded.
* $p < .05$ (uncorrected, two-tailed). ** $p < .01$ (uncorrected, two-tailed).

openness. Removing rhythm decreased the likelihood of the observed data by a factor of 1.78, whereas removing memory for music increased the likelihood by 1.37—very weak effects that differed minimally. For grammar, the observed data were 60.3 times more likely with a model that included rhythm and memory for music in addition to IQ. The observed data were 1.17 times less likely when rhythm was removed and 1.02 times more likely when memory for music was removed. Again, both differences were minuscule. In short, rhythm and memory for music were similarly good at predicting speech perception and grammar, and it mattered little whether we used either or both predictors.

Discussion

Children's performance on tests of speech perception and grammar was predicted best by IQ and musical ability, even when duration of music training, demographic variables, working memory, and openness to experience were held constant. The partial association with musical ability (with training held constant) suggests that the link stems primarily from predispositions. When more specific aspects of musical ability (melody discrimination, rhythm discrimination, long-term memory for music) were considered separately, rhythm and memory for music predicted language abilities (in combination with IQ), but melody did not. Across analyses, associations with formal training in music were relatively small compared with associations with musical ability.

In fact, after controlling for confounding variables, there were no positive associations between language abilities and music training. Moreover, even *simple* associations with music training were weak (grammar) or absent (speech perception; Table 1), despite the fact that we coded music training to maximize such associations. The results from Bayesian statistics, which are more robust against issues of power, make it unlikely that meaningful associations would emerge with a larger sample, even though evidence for the null hypothesis was not strong. These findings raise doubts about the view that music training *causes* improvements in a wide range of language abilities (e.g., Kraus & Chandrasekaran, 2010; Patel, 2011). After all, if a causal phenomenon is unaccompanied by correlations in the real world, the putative effect is either restricted to the laboratory, very weak, or nonexistent. Moreover, our music-training data were not anomalous in the context of the published literature. As in previous research, duration of music training was correlated positively with IQ, musical ability, and openness (Table 1; Corrigall et al., 2013; Schellenberg, 2006; Swaminathan & Schellenberg, 2018b).

Perhaps null partial associations between music training and language abilities are unsurprising considering that causal evidence in this regard (i.e., from studies with random assignment and an active control group) is unconvincing and because the hypothesized link is analogous to proposing that training in mathematics promotes better reading comprehension. Although mathematical ability and reading ability are correlated, as are virtually all "narrow" cognitive abilities, such correlations are a reflection of general cognitive ability (Carroll, 1993), and far-transfer effects (between distantly related domains) are rare if not impossible (Sala & Gobet, 2017).

In fact, evidence that music training causes improvements in language abilities among typically developing school-age children comes from studies with an inordinate amount of attrition and a

Table 3
Partial Associations Among Variables (Controlling for Age and Bilingualism)

Variable	Grammar	Music training	Musical ability	IQ	Working memory	Openness
Speech perception	.333**	−.070	.251*	.191	.185	−.115
Grammar		.103	.414**	.415**	.361**	.235*
Music training			.335**	.375**	.051	.216*
Musical ability				.234*	.410**	.308**
IQ					.275**	.222*
Working memory						.097

* $p \leq .05$ (uncorrected, two-tailed). ** $p \leq .01$ (uncorrected, two-tailed).

Table 4
Results From Multiple-Regression Models Predicting Speech Perception and Grammar

Variable	Speech perception β	Speech perception *p*	Grammar β	Grammar *p*
Music training	−.211	.052	−.143	.146
Musical ability	.329	.007	.299	.007
Age	.192	.125	.076	.504
Bilingualism	.157	.080	−.069	.398
IQ	.291	.035	.416	.001
Working memory	.014	.890	.132	.168
Openness	−.193	.039	.075	.377
Model				
R^2	.389	<.001	.490	<.001
Adjusted R^2	.337	<.001	.447	<.001
F(7, 83)	7.535	<.001	11.394	<.001

Note. Bilingualism (0 = *monolingual*, 1 = *other*) was dummy coded.

passive control group (Slater et al., 2015); a task—with pitch cues—that favored the music group over controls (François, Chobert, Besson, & Schön, 2013); or positive results for only one of three word-reading tests, the one that was the least expected (Moreno et al., 2009). Studies of younger children with random assignment and active control groups have tended to focus on improving listening skills in the music intervention, rather than on learning to sing or play an instrument. The findings highlight improvements in phonological awareness among 5-year-old German children after 100 music-training sessions (Degé & Schwarzer, 2011; Patscheke, Degé, & Schwarzer, 2016) or improvements in vocabulary *and* inhibition among 4- to 6-year-old Canadian children after 20 sessions (Moreno et al., 2011). The latter result raises the possibility that associations with music training generalize beyond language. In any event, evidence that music training selectively causes improvements in language abilities is limited.

Our results confirmed, however, that rhythm discrimination was positively associated with language abilities (along with IQ), even when other confounding variables were held constant. This finding is consistent with predictions from Goswami (2011) and Gordon, Shivers, et al. (2015), who propose a link between rhythm and speech perception and a link between rhythm and grammar, respectively. The best evidence that rhythm training causes language improvements comes from an intervention that provided rhythm-based music training to Italian 8- to 11-year-olds with dyslexia (Flaugnacco et al., 2015). The training caused improvements in performance on tests of phonological awareness and early reading ability. Similar interventions for children with hearing loss report similar results (Hidalgo, Falk, & Schön, 2017; Hidalgo, Pesnot-Lerousseau, Marquis, Roman, & Schön, 2019). Perhaps music training has a reliable impact on language abilities only among children who have language difficulties and therefore much room for improvement. In the present investigation, we replicated the association between rhythm and language among typically developing Canadian children in a real-world context. Nevertheless, we also found that performance on a test of memory for music was as good as rhythm at predicting speech perception *and* grammar. Thus, for typically developing children who take run-of-the-mill music lessons, the link between musical ability and language ability may be meaningful because it is independent of SES, general cognitive ability, and personality, but it does not appear to be specific to rhythm.

The present response patterns are remarkably consistent with results from twin studies, which indicate that the role of practice and training in many areas (e.g., music, sports, professions; Ericsson, Krampe, & Tesch-Römer, 1993) has been overestimated (Macnamara, Hambrick, & Oswald, 2014). For example, musical achievement is a consequence of gene–environment interactions, such that genetics influences the amount of practice, with practice being particularly important for those with a predisposition for music (Hambrick & Tucker-Drob, 2015). When genetics is held constant by limiting the sample to monozygotic twins, musical ability is independent of practice (Mosing, Madison, Pedersen, Kuja-Halkola, & Ullén, 2014). Moreover, the link between practicing music and general cognitive ability is determined primarily by genetics (Mosing, Madison, Pedersen, & Ullén, 2016), as is the link between musical ability and general cognitive ability (Mosing, Pedersen, Madison, & Ullén, 2014). In fact, musical ability appears to be determined by two independent genetic factors: one associated with general cognitive ability, the other specifically with musical ability (Mosing, Pedersen, et al., 2014). These same two genetic factors may also influence language abilities and account for the overlap with musical ability. In the present study, both of our language measures were predicted jointly by IQ and musical ability.

Future research could attempt to replicate the present findings with multiple measures of working memory, speech perception, grammar, or other language abilities and with samples of children from different cultures. The weak associations with music training reported here could also be a consequence of the training not being intensive enough; future research could examine more intensive training or vary the intensity systematically. It would also be interesting to measure musical expertise as lower-level perceptual abilities (e.g., gap detection) or higher-level cognitive abilities (e.g., musical expectancies) to determine the limits of associations between musical and language abilities and, ultimately, to inform theories of links between music and language. Such endeavors could improve our understanding of the structure of the intellect in general and the role of musical ability in particular (Carroll, 1993; Peretz & Coltheart, 2003).

Table 5
Correlations and Partial Correlations (With Age and Bilingualism Held Constant) Between Subtests From the MBEMA and Other Variables

Variable	Musical ability (MBEMA) Melody *r*	Melody *pr*	Rhythm *r*	Rhythm *pr*	Memory for music *r*	Memory for music *pr*
Speech perception	.206*	.035	.443**	.301**	.403**	.249*
Grammar	.353**	.202	.527**	.404**	.505**	.370**
Music training	.372**	.270*	.356**	.230*	.415**	.300**
IQ	.358**	.152	.446**	.235*	.406**	.167
Working memory	.329**	.233*	.499**	.416**	.415**	.317**
Openness	.206*	.198	.262*	.260*	.273**	.274**

Note. MBEMA = Montreal Battery of Evaluation of Musical Abilities.
* $p \leq .05$ (uncorrected, two-tailed). ** $p \leq .01$ (uncorrected, two-tailed).

Table 6
Results From Regression Models (Standardized Slopes) Predicting Speech Perception and Grammar

	Speech perception			Grammar		
Variable	Melody	Rhythm	Memory	Melody	Rhythm	Memory
Music training	−.133	−.176	−.202	−.086	−.104	−.132
Musical ability	**.034**	**.325****	**.301****	**.087**	**.249***	**.261****
Age	.278*	.221	.202	.141	.112	.089
Bilingualism	.149	.148	.153	−.073	−.077	−.073
IQ	.284*	.270*	.305*	.411**	.398**	.427**
Working memory	.123	.010	.044	.219*	.146	.162
Openness	−.136	−.185*	−.186*	.120	.090	.084
Model						
R^2	.333**	.397**	.390**	.449**	.482**	.487**
Adjusted R^2	.277**	.346**	.338**	.403**	.438**	.443**
$F(7, 83)$	5.920**	7.813**	7.568**	9.668**	11.020**	11.239**

Note. The musical ability variable (bold type) was melody, rhythm, or memory for music (memory). Bilingualism (0 = *monolingual*, 1 = *other*) was dummy coded.
* $p \leq .05$ (uncorrected, two-tailed). ** $p \leq .01$ (uncorrected, two-tailed).

Having found little support for the theories we sought to test, one might ask why and how these theories were formulated in the first place. Over the last 20 years, as it became clear that the brain remains plastic throughout the life span (e.g., Doidge, 2007), reported associations between music and nonmusical abilities were often presumed to be causal—a consequence of plasticity (Schellenberg, 2019). The present data confirm that the association between musical ability and language ability is meaningful because it is not an artifact of confounding variables. Music lessons appear to play a very minor role, however, and musical abilities other than rhythm processing may be equally important predictors of language skills.

References

Best, C. T., McRoberts, G. W., & Goodell, E. (2001). Discrimination of non-native consonant contrasts varying in perceptual assimilation to the listener's native phonological system. *Journal of the Acoustical Society of America, 109,* 775–794. http://dx.doi.org/10.1121/1.1332378

Best, C. T., McRoberts, G. W., & Sithole, N. M. (1988). Examination of perceptual reorganization for nonnative speech contrasts: Zulu click discrimination by English-speaking adults and infants. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 345–360. http://dx.doi.org/10.1037/0096-1523.14.3.345

Bhatara, A., Yeung, H. H., & Nazzi, T. (2015). Foreign language learning in French speakers is associated with rhythm perception, but not with melody perception. *Journal of Experimental Psychology: Human Perception and Performance, 41,* 277–282. http://dx.doi.org/10.1037/a0038736

Bishop, D. V. M. (2003). *Test for Reception of Grammar—Version 2*. London, England: Psychological Corporation.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge, UK: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511571312

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Corrigall, K. A., Schellenberg, E. G., & Misura, N. M. (2013). Music training, cognition, and personality. *Frontiers in Psychology, 4,* 222. http://dx.doi.org/10.3389/fpsyg.2013.00222

Corriveau, K., Pasquini, E., & Goswami, U. (2007). Basic auditory processing skills and specific language impairment: A new look at an old hypothesis. *Journal of Speech, Language, and Hearing Research, 50,* 647–666. http://dx.doi.org/10.1044/1092-4388(2007/046)

Corriveau, K. H., & Goswami, U. (2009). Rhythmic motor entrainment in children with speech and language impairments: Tapping to the beat. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior, 45,* 119–130. http://dx.doi.org/10.1016/j.cortex.2007.09.008

Darlington, R. B. (1990). *Regression and linear models*. New York, NY: McGraw-Hill.

Degé, F., & Schwarzer, G. (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology, 2,* 124. http://dx.doi.org/10.3389/fpsyg.2011.00124

Doidge, N. (2007). *The brain that changes itself*. New York, NY: Penguin.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100,* 363–406. http://dx.doi.org/10.1037/0033-295X.100.3.363

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41,* 1149–1160. http://dx.doi.org/10.3758/BRM.41.4.1149

Fernald, A., & McRoberts, G. (1996). Prosodic bootstrapping: A critical analysis of the argument and the evidence. In J. L. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 365–388). Mahwah, NJ: Erlbaum.

Flaugnacco, E., Lopez, L., Terribili, C., Montico, M., Zoia, S., & Schön, D. (2015). Music training increases phonological awareness and reading skills in developmental dyslexia: A randomized control trial. *PLoS ONE, 10,* e0138715. http://dx.doi.org/10.1371/journal.pone.0138715

François, C., Chobert, J., Besson, M., & Schön, D. (2013). Music training for the development of speech segmentation. *Cerebral Cortex, 23,* 2038–2043. http://dx.doi.org/10.1093/cercor/bhs180

Gordon, R. L., Fehd, H. M., & McCandliss, B. D. (2015). Does music training enhance literacy skills? A meta-analysis. *Frontiers in Psychology, 6,* 1777. http://dx.doi.org/10.3389/fpsyg.2015.01777

Gordon, R. L., Jacobs, M. S., Schuele, C. M., & McAuley, J. D. (2015). Perspectives on the rhythm-grammar link and its implications for typical and atypical language development. *Annals of the New York Academy of Sciences, 1337,* 16–25. http://dx.doi.org/10.1111/nyas.12683

Gordon, R. L., Shivers, C. M., Wieland, E. A., Kotz, S. A., Yoder, P. J., & Devin McAuley, J. (2015). Musical rhythm discrimination explains individual differences in grammar skills in children. *Developmental Science, 18,* 635–644. http://dx.doi.org/10.1111/desc.12230

Goswami, U. (2011). Language, music, and children's brains: A rhythmic timing perspective on language and music as cognitive systems. In P. Rebuschat, M. Rohrmeier, J. A. Hawkins, & I. Cross (Eds.), *Language and music as cognitive systems* (pp. 292–301). Oxford, UK: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780199553426.003.0030

Hambrick, D. Z., & Tucker-Drob, E. M. (2015). The genetics of music accomplishment: Evidence for gene-environment correlation and interaction. *Psychonomic Bulletin & Review, 22,* 112–120. http://dx.doi.org/10.3758/s13423-014-0671-9

Hansen, M., Wallentin, M., & Vuust, P. (2013). Working memory and musical competence of musicians and non-musicians. *Psychology of Music, 41,* 779–793. http://dx.doi.org/10.1177/0305735612452186

Hausen, M., Torppa, R., Salmela, V. R., Vainio, M., & Särkämö, T. (2013). Music and speech prosody: A common rhythm. *Frontiers in Psychology, 4,* 566. http://dx.doi.org/10.3389/fpsyg.2013.00566

Hidalgo, C., Falk, S., & Schön, D. (2017). Speak on time! Effects of a musical rhythmic training on children with hearing loss. *Hearing Research, 351,* 11–18. http://dx.doi.org/10.1016/j.heares.2017.05.006

Hidalgo, C., Pesnot-Lerousseau, J., Marquis, P., Roman, S., & Schön, D. (2019). Rhythmic training improves temporal anticipation and adaptation abilities in children with hearing loss during verbal interaction. *Journal of Speech, Language, and Hearing Research*. Advance online publication. http://dx.doi.org/10.1044/2019_JSLHR-S-18-0349

JASP Team. (2019). JASP (Version 0.11.0) [Computer software]. Amsterdam, the Netherlands: Author.

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five Inventory—Versions 4a and 54*. Berkeley: University of California, Institute of Personality and Social Research.

John, O. P., Naumann, L. P., & Soto, C. J. (2008). Paradigm shift to the integrative big-five trait taxonomy: History, measurement, and conceptual issues. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (pp. 114–158). New York, NY: Guilford Press.

Kraus, N., & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature Reviews Neuroscience, 11,* 599–605. http://dx.doi.org/10.1038/nrn2882

Kraus, N., & Nicol, T. (2018). Brainstem encoding of speech and music sounds in humans. In K. Kandler (Ed.), *Oxford handbook of the auditory brainstem*. Oxford, UK: Oxford University Press. Advance online publication.

Loui, P., Raine, L. B., Chaddock-Heyman, L., Kramer, A. F., & Hillman, C. H. (2019). Musical instrument practice predicts white matter microstructure and cognitive abilities in childhood. *Frontiers in Psychology, 10,* 1198. http://dx.doi.org/10.3389/fpsyg.2019.01198

Macnamara, B. N., Hambrick, D. Z., & Oswald, F. L. (2014). Deliberate practice and performance in music, games, sports, education, and professions: A meta-analysis. *Psychological Science, 25,* 1608–1618. http://dx.doi.org/10.1177/0956797614535810

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological Science, 22,* 1425–1433. http://dx.doi.org/10.1177/0956797611416999

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. http://dx.doi.org/10.1093/cercor/bhn120

Mosing, M. A., Madison, G., Pedersen, N. L., Kuja-Halkola, R., & Ullén, F. (2014). Practice does not make perfect: No causal effect of music practice on music ability. *Psychological Science, 25,* 1795–1803. http://dx.doi.org/10.1177/0956797614541990

Mosing, M. A., Madison, G., Pedersen, N. L., & Ullén, F. (2016). Investigating cognitive transfer within the framework of music practice: Genetic pleiotropy rather than causality. *Developmental Science, 19,* 504–512. http://dx.doi.org/10.1111/desc.12306

Mosing, M. A., Pedersen, N. L., Madison, G., & Ullén, F. (2014). Genetic pleiotropy explains associations between musical auditory discrimination and intelligence. *PLoS ONE, 9,* e113874. http://dx.doi.org/10.1371/journal.pone.0113874

Patel, A. D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology, 2,* 142. http://dx.doi.org/10.3389/fpsyg.2011.00142

Patel, A. D. (2014). Can nonlinguistic musical training change the way the brain processes speech? The expanded OPERA hypothesis. *Hearing Research, 308,* 98–108. http://dx.doi.org/10.1016/j.heares.2013.08.011

Patel, A. D., & Iversen, J. R. (2007). The linguistic benefits of musical abilities. *Trends in Cognitive Sciences, 11,* 369–372. http://dx.doi.org/10.1016/j.tics.2007.08.003

Patscheke, H., Degé, F., & Schwarzer, G. (2016). The effects of training in music and phonological skills on phonological awareness in 4- to 6-year-old children of immigrant families. *Frontiers in Psychology, 7,* 1647. http://dx.doi.org/10.3389/fpsyg.2016.01647

Patscheke, H., Degé, F., & Schwarzer, G. (2019). The effects of training in rhythm and pitch on phonological awareness in four- to six-year-old children. *Psychology of Music, 47,* 376–391. http://dx.doi.org/10.1177/0305735618756763

Peretz, I., & Coltheart, M. (2003). Modularity of music processing. *Nature Neuroscience, 6,* 688–691. http://dx.doi.org/10.1038/nn1083

Peretz, I., Gosselin, N., Nan, Y., Caron-Caplette, E., Trehub, S. E., & Béland, R. (2013). A novel tool for evaluating children's musical abilities across age and culture. *Frontiers in Systems Neuroscience, 7,* 30. http://dx.doi.org/10.3389/fnsys.2013.00030

Politimou, N., Dalla Bella, S., Farrugia, N., & Franco, F. (2019). Born to speak and sing: Musical predictors of language development in preschoolers. *Frontiers in Psychology, 10,* 948. http://dx.doi.org/10.3389/fpsyg.2019.00948

Port, R. (2007). How are words stored in memory? Beyond phones and phonemes. *New Ideas in Psychology, 25,* 143–170. http://dx.doi.org/10.1016/j.newideapsych.2007.02.001

Roncaglia-Denissen, M. P., Schmidt-Kassow, M., & Kotz, S. A. (2013). Speech rhythm facilitates syntactic ambiguity resolution: ERP evidence. *PLoS ONE, 8,* e56000. http://dx.doi.org/10.1371/journal.pone.0056000

Rothermich, K., Schmidt-Kassow, M., & Kotz, S. A. (2012). Rhythm's gonna get you: Regular meter facilitates semantic sentence processing. *Neuropsychologia, 50,* 232–244. http://dx.doi.org/10.1016/j.neuropsychologia.2011.10.025

Sala, G., & Gobet, F. (2017). Does far transfer exist? Negative evidence from chess, music, and working memory training. *Current Directions in Psychological Science, 26,* 515–520. http://dx.doi.org/10.1177/0963721417712760

Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology, 98,* 457–468. http://dx.doi.org/10.1037/0022-0663.98.2.457

Schellenberg, E. G. (2019). Correlation = causation? Music training, psychology, and neuroscience. *Psychology of Aesthetics, Creativity, and the Arts*. Advance online publication. http://dx.doi.org/10.1037/aca0000263

Schellenberg, E. G., & Weiss, M. W. (2013). Music and cognitive abilities. In D. Deutsch (Ed.), *The psychology of music* (3rd ed., pp. 499–550). Amsterdam, the Netherlands: Elsevier. http://dx.doi.org/10.1016/B978-0-12-381460-9.00012-2

Slater, J., Skoe, E., Strait, D. L., O'Connell, S., Thompson, E., & Kraus, N. (2015). Music training improves speech-in-noise perception: Longitudinal evidence from a community-based music program. *Behavioural Brain Research, 291,* 244–252. http://dx.doi.org/10.1016/j.bbr.2015.05.026

Swaminathan, S., & Gopinath, J. K. (2013). Music training and second-language English comprehension and vocabulary skills in Indian children. *Psychological Studies, 58,* 164–170. http://dx.doi.org/10.1007/s12646-013-0180-3

Swaminathan, S., & Schellenberg, E. G. (2017). Musical competence and phoneme perception in a foreign language. *Psychonomic Bulletin & Review, 24,* 1929–1934. http://dx.doi.org/10.3758/s13423-017-1244-5

Swaminathan, S., & Schellenberg, E. G. (2018a). Music training and cognitive abilities: Associations, causes, and consequences. In M. H. Thaut & D. A. Hodges (Eds.), *The Oxford handbook of music and the brain*. New York, NY: Oxford University Press. http://dx.doi.org/10.1093/oxfordhb/9780198804123.013.26

Swaminathan, S., & Schellenberg, E. G. (2018b). Musical competence is predicted by music training, cognitive abilities, and personality. *Scientific Reports, 8,* 9223. http://dx.doi.org/10.1038/s41598-018-27571-2

Swaminathan, S., Schellenberg, E. G., & Venkatesan, K. (2018). Explaining the association between music training and reading in adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44,* 992–999. http://dx.doi.org/10.1037/xlm0000493

Tallal, P., & Gaab, N. (2006). Dynamic auditory processing, musical experience and language development. *Trends in Neurosciences, 29,* 382–390. http://dx.doi.org/10.1016/j.tins.2006.06.003

Tierney, A., & Kraus, N. (2013). Music training for the development of reading skills. *Progress in Brain Research, 207,* 209–241. http://dx.doi.org/10.1016/B978-0-444-63327-9.00008-4

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence* (2nd ed.). San Antonio, TX: Psychological Corporation.

Received June 19, 2019
Revision received October 3, 2019
Accepted October 16, 2019 ■