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OBSERVATION

Is Musical Expertise Associated With Self-Reported Foreign-Language Ability?

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Many claims have been made about links between musical expertise and language ability. Rhythm ability, in particular, has been shown to predict phonological, grammatical, and second-language (L2) abilities, whereas music training often predicts reading and speech-perception skills. Here, we asked whether musical expertise—musical ability and/or music training—relates to L2 (English) abilities of Portuguese native speakers. Participants ($N = 154$) rated their L2 ability on seven 7-point scales, one each for speaking, reading, writing, comprehension, vocabulary, fluency, and accent. They also completed a test of general cognitive ability, an objective test of musical ability with melody and rhythm subtests, and a questionnaire that measured music training and other aspects of musical behaviors. L2 ability correlated positively with education and cognitive ability but not with music training. It also had no association with musical ability or with self-reports of musical behaviors. Moreover, Bayesian analyses provided evidence for the *null* hypotheses (i.e., no link between L2 and rhythm ability, no link between L2 and years of music lessons). In short, our findings—based on participants' self-reports of L2 ability—raise doubts about proposed associations between musical and second-language abilities, which may be limited to specific populations or measures.

Public Significance Statement
Scholars, the media, and the general public have been intrigued by the idea of associations between musical ability and nonmusical abilities, including second-language proficiency. In contrast to previous results, however, in the present study, we did *not* find an association between second-language abilities and music training, or between second-language proficiency and musical ability (melody or rhythm skills). Our results raise doubts about (a) theories of links between music and language in general, and music and second-language ability in particular, and (b) advocating for the inclusion of music training in school curricula because of its nonmusical by-products.

Keywords: music, training, ability, language, transfer

Supplemental materials: https://doi.org/10.1037/xhp0001116.supp

Associations between musical expertise and language ability are the focus of much research (for review see Nayak et al., 2022). Some theorists (e.g., Patel, 2011, 2014; Tierney & Kraus, 2013) propose that formal music training improves language ability, focusing on transfer from music to language. Others consider overlapping genetic contributions and neural substrates (Nayak et al., 2022; Sammler & Elmer, 2020; Turker & Reiterer, 2021), acknowledging that natural musical ability influences who takes music lessons.

The relevant research on music training typically precludes inferences of causation (Schellenberg, 2020). Although associations between training and language abilities (e.g., speech perception, reading skills) abound, these could stem from general cognitive abilities (e.g., Swaminathan et al., 2018; Tierney et al., 2020). Moreover, a meta-analysis of longitudinal studies on music training and language abilities was inconclusive because publication bias could not be ruled out as a contributing factor to the observed but small benefit of music training (Neves et al., 2022).

Studies of associations between musical *ability* and language are motivated by proposals that the same genetically determined mechanisms (e.g., working memory, entrainment; Nayak et al., 2022) are used across domains (e.g., Kraus & Slater, 2016; Ladányi et al., 2023; Patel & Morgan, 2017; Tervaniemi et al., 2021). As with most human traits, musical ability varies normally in the general population and can be tested among individuals with or without music training (e.g., Law & Zentner, 2012; Wallentin et al., 2010). *Rhythm* abilities

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are thought to be particularly important because temporal processing is central to phonological/syntactical processing and to music (Gordon, Jacobs, et al., 2015; Goswami et al., 2016; Tallal & Gaab, 2006).

Indeed, children's and adults' rhythm- but not melody-discrimination abilities correlate with their perception of nonnative phonemes (Swaminathan & Schellenberg, 2017, 2020). Rhythm abilities also predict children's grammatical skills even when general cognitive ability is held constant (Gordon, Shivers, et al., 2015; Swaminathan & Schellenberg, 2020). Although rhythm abilities predict language ability better than melody abilities do, a third facet of musical ability (memory for tunes) can have associations with language similar in magnitude to those observed for rhythm (Swaminathan & Schellenberg, 2020). In one instance (Anvari et al., 2002), melody abilities better predicted the pre-reading skills of 4- and 5-year-olds compared to rhythm abilities. Thus, the "special" association between rhythm and language may be unreliable, or dependent on age or which other aspects of musical ability are considered.

Here, we asked whether musical expertise—training *or* ability—correlates with second-language (L2) proficiency, and whether rhythm ability plays a special role. Music training and musical ability are correlated positively, and both variables correlate with general cognitive ability, although the association is stronger for rhythm than for melody (e.g., Correia et al., 2022; Swaminathan et al., 2021). Music *training* predicts U.S. undergraduates' ability to speak in Spanish (Posedel et al., 2012), Indian children's English word-reading ability (Swaminathan & Gopinath, 2013), and Italian 11- to 15-year-olds' performance on an English spelling test (Talamini et al., 2018). Musical *ability* also correlates with L2 proficiency (for reviews see Milovanov & Tervaniemi, 2011; Nayak et al., 2022). Among Finnish children and adults, L2 (English) pronunciation is better for those with higher levels of musical ability (Milovanov et al., 2008, 2010). Musical abilities also predict English-speaking adults' ability to produce and perceive Mandarin tone-words (Li & DeKeyser, 2017), and German speakers' ability to fake a French accent (Coumel et al., 2019). For Japanese immigrants to the United States, English receptive and productive phonological abilities correlate with musical ability, even after accounting for the age of arrival and duration of time in the United States (Slevc & Miyake, 2006).

To date, no study has examined rhythm separately from other aspects of musical ability, except for one study of French speakers, whose rhythm- but not melody-discrimination abilities were correlated with their years of foreign-language training (Bhatara et al., 2015). Because general cognitive ability was not measured, high-functioning individuals may have had more foreign-language courses *and* better rhythm skills. The present study was a conceptual replication and extension of Bhatara et al., using the same rhythm and melody tests, but including a test of cognitive ability and a self-report measure with seven different dimensions of L2 proficiency.

Although self-reports are suboptimal compared to measuring actual behavior (Baumeister et al., 2007; Kaushanskaya et al., 2020), an objective evaluation of L2 ability (reading, speaking, writing, and so on) with a large sample is difficult to implement in an online study. Regardless, self-reports of L2 proficiency correlate strongly with objective tests (Kaushanskaya et al., 2020; Marian et al., 2007), even when participants who provide high self-ratings overestimate their ability (Shi, 2011). Our measure, from Swaminathan et al. (2021), included items from an established inventory (i.e., speaking, comprehension, reading, and accent; Marian et al., 2007). Evidence for its validity comes from speakers of tonal languages, who completed the scale in relation to their particular tonal language (primarily Mandarin or Cantonese; Swaminathan et al., 2021). Their L2 scores correlated positively with performance on a test of melody (but not rhythm) ability. Presumably, facility at identifying words that vary in pitch or contour generalizes to melodies.

Previous reports using objective tests of L2 ability measured pronunciation (Milovanov et al., 2008), pronunciation and phonemic discrimination (Milovanov et al., 2010), or the perception and production of isolated words (Li & DeKeyser, 2017). Coumel et al. (2019) examined how well German participants could speak *German* with a French accent, not their proficiency with L2 (French). Slevc and Miyake's (2006) study was exemplary because native Japanese speakers living in the United States took four tests (receptive phonology, productive phonology, grammar, and idioms). Although we contend that our L2 self-reports were a suitable option for online testing, we make no claim that they were equivalent to a battery of objective tests.

Method

Transparency and Openness

The data (https://osf.io/9uqn6/?view_only=046b526514524c559bd91f8a3bd86907) and stimuli/procedures (https://app.gorilla.sc/openmaterials/218554) are available online. This study was not preregistered.

Participants

The research protocol was approved by Iscte's ethics committee (reference 07/2021). Participants were 154 native Portuguese speakers: 39 men, 115 women, a gender imbalance typical of samples recruited identically (e.g., Correia et al., 2023: 76% women). The sample had 89% power to detect partial correlations of 0.25 or greater (three covariates; Faul et al., 2007). The mean age was 23.8 years ($SD = 7.5$, range: 18–55); 79% were 25 or younger. Only one participant had not completed high school; 94, 44, 14, and 1 had a high-school, bachelor's, master's, or doctoral degree, respectively. Almost half ($n = 70$) had no formal music lessons. Others had 6 months ($n = 6$), 1 year ($n = 19$), 2 years ($n = 16$), 3–5 years ($n = 18$), 6–9 years ($n = 17$), or at least 10 years ($n = 8$).

Measures

Self-Report Questionnaires

A background questionnaire measured age, sex, education, and native language. Following Swaminathan et al. (2021), participants rated their English proficiency from 1 (*no knowledge*) to 7 (*perfect knowledge*) on separate scales for Speaking, Reading, Writing, Comprehension, Vocabulary, Fluency, and Accent.[1]

Musical expertise and activities were measured with the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014; Portuguese translation: Lima et al., 2020), which has five subscales (Active Engagement, Perceptual Abilities, Music Training, Singing

[1] Onset of L2 learning was not informative because almost all Portuguese children start studying English in 5th grade.

Abilities, and Emotions) and an aggregate (General Factor) score. (Capitalized words indicate measured variables.) Example items are provided in Table 1. For statistical analyses of music training, we used (a) the Music Training subscale, which considers not only lessons but also lifelong practice, hours of practice, music theory, number of instruments played, compliments, and whether participants identify as musicians, and (b) *years of music lessons*, a single item from the same subscale.

Objective Ability Tests

The 8-min Matrix Reasoning Item Bank (MaRs-IB; Chierchia et al., 2019) is an 8-min test of general cognitive ability modeled after Raven's matrices tests. On each trial, a 3 × 3 matrix was presented with one empty cell. The other eight cells illustrated abstract shapes that varied systematically on one to four dimensions. On each trial, participants selected one of four options for the missing cell. For statistical analysis, proportion-correct scores were logit-transformed.

The 20-min Musical Ear Test (MET; Wallentin et al., 2010) has Melody and Rhythm subtests (in that order), both with 52 trials (26 *same*, 26 *different*), and good reliability and validity (Correia et al., 2022; Swaminathan et al., 2021). On each trial, listeners heard two sequences of tones (Melody) or drumbeats (Rhythm) and judged whether the second sequence was identical to the first. On *different* trials, at least one tone or drumbeat was displaced in pitch or time, respectively. Each sequence in the Melody subtest began on the downbeat of one measure and ended on the next downbeat (4/4 time), with downbeats separated by 2,400 ms. Rhythm sequences were similarly structured except for syncopated sequences that did not begin or end on downbeats. Some participants had missing data (Melody: $n = 11$; Rhythm, $n = 6$).

Procedure

A 40-min session in *Gorilla* (Anwyl-Irvine et al., 2020) comprised questionnaires (demographics, L2, then Gold-MSI) followed by objective tests (MaRs-IB then MET).

Table 1
Two Sample Items from Each Subscale of the Gold-MSI

Subscale	Sample items
Active engagement	I spend a lot of my free time doing music-related activities.
	I often read or search the internet for things related to music.
Perceptual abilities	I can compare and discuss differences between two performances or versions of the same piece of music.
	I can tell when people sing or play out of tune.
Music training	I have had _____ years of formal training on a musical instrument (including voice) during my lifetime.[a]
	I would not consider myself a musician. (reverse coded)
Singing abilities	I am able to hit the right notes when I sing along with a recording.
	After hearing a new song two or three times, I can usually sing it by myself.
Emotions	I am able to talk about the emotions that a piece of music evokes for me.
	Music can evoke my memories of past people and places.

Note. For 31 of 39 items, responses were made on scales from 1 (completely agree) to 7 (completely disagree). [a] Response options were made on a different 7-point ordinal scale: 0, 0.5, 1, 2, 3–5, 6–9, or 10 or more years.

Statistical Analyses

We initially compared the different L2 ratings and asked whether L2 ability was associated with demographics. After testing for correlations among the music variables, we examined whether musical abilities and music training predicted L2 abilities.

Results

Descriptive statistics are provided in Table 2. A repeated-measures ANOVA confirmed that participants' ratings varied across the L2 items, $F(6, 918) = 64.98$, $p < .001$, partial $\eta^2 = 0.298$ (see Figure 1). Ratings were highest for comprehension and reading, which did not differ, and lowest for accent (Holm corrected). Speaking, vocabulary, and writing fell between and did not differ. Speaking and vocabulary (but not writing) were also higher than fluency.

Pairwise correlations among ratings ranged from $r = .566$ (*comprehension* and *accent*) to $r = .887$ (*speaking* and *fluency*), $Ns = 154$, $ps < .001$. In order to improve construct validity, reduce redundancy, and eliminate item-specific measurement error, and because we had no hypotheses about different facets of L2 proficiency, we extracted the principal component (hereafter *L2 ability*) for subsequent analyses. L2 ability accounted for 80% of the variance in the original ratings.

Tests of demographic variables revealed that men provided higher L2 self-ratings compared to women, $t(152) = 2.25$, $p = .026$, Cohen's $d = 0.416$. L2 ability also had small positive associations with education, $r = .243$, $N = 154$, $p = .002$, and cognitive ability, $r = .158$, $N = 154$, $p = .050$, but not with age, $p = .149$. Gender, education, and cognitive ability were held constant in the main analyses.

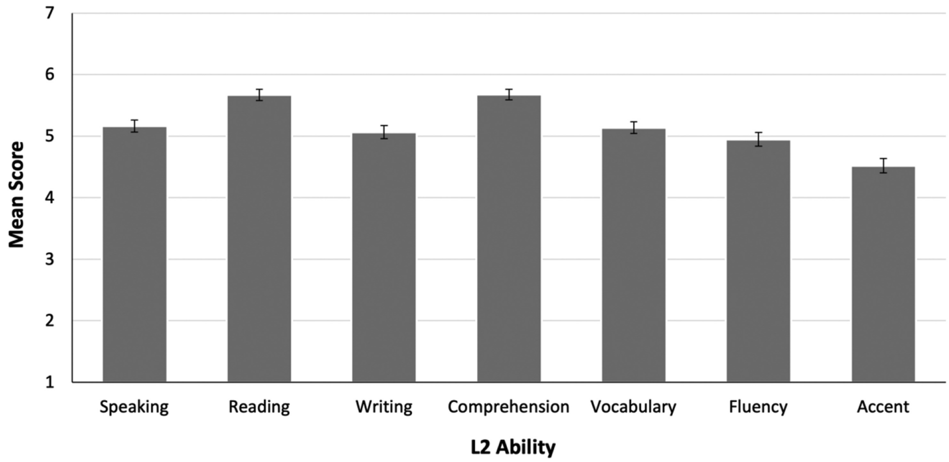
Table 2
Descriptive Statistics

Study variable	*n*	*M*	*SD*	Median	Min	Max
L2 self-ratings						
Speaking	154	5.16	1.22	5	2	7
Reading	154	5.67	1.13	6	2	7
Writing	154	5.06	1.29	5	1	7
Comprehension	154	5.68	1.07	6	1	7
Vocabulary	154	5.14	1.17	5	1	7
Fluency	154	4.95	1.38	5	1	7
Accent	154	4.52	1.45	5	1	7
Gold-MSI						
Active engagement	154	4.00	1.10	3.94	1.44	6.89
Perceptual abilities	154	5.10	0.88	5.10	2.56	6.78
Music training	154	2.89	1.60	2.50	1.00	6.57
Singing abilities	154	3.89	1.04	3.86	1.14	6.86
Emotions	154	5.74	0.81	6.00	3.33	7.00
General factor	154	3.79	1.01	3.78	1.72	6.44
Years of music lessons	154	2.93	2.07	3.00	1.00	7.00
MET						
Melody	143	34.09	6.00	34	21	49
Rhythm	148	35.28	5.69	34	21	49
Cognitive ability						
MaRs-IB (% correct)	154	61.3	16.3	63.6	24.1	94.6

Note. Gold-MSI = Goldsmiths Musical Sophistication Index; MET = musical ear test.

Figure 1

Means on the Seven Individual Items From the Test of L2 Ability



Note. Error bars are *SE*s.

MET Melody and Rhythm scores were correlated, $r = .555$, $n = 141$, $p < .001$, and both scores correlated with Gold-MSI scores (see Table 3). Exceptions included null associations between both MET subtests and Emotions, and between Melody and Active Engagement.

As shown in Table 4 and Figure 2, L2 ability was *not* correlated with Melody or Rhythm scores, or with the Gold-MSI subscales, the General Factor, or years of music lessons. Bayesian statistics (JASP 0.16.4, default priors; JASP Team, 2022) determined whether the observed data were more likely under the null or alternative hypothesis. Following convention (Lee & Wagenmakers, 2014), a Bayes factor (BF_{10}, reported here with three-digit accuracy) of 3.00 or more provided evidence for the alternative hypothesis; reciprocal values ($\leq$0.333) provided evidence for the null. When $BF_{10} = 1.00$, the data were equally likely under the null or alternative hypothesis.

As shown in Table 3, Bayes factors provided evidence for pairwise correlations among the music variables, except for associations between either MET subtest and Emotions. For the association between L2 ability and Rhythm, however, and between L2 ability and years of music lessons (Table 4), the observed data provided evidence for the *null* hypothesis, a finding that extended to a null association between L2 ability and Active Engagement. The other six Bayes factors were less than 1.00, which is improbable if the alternative and null hypotheses were equally likely in each case ($p = .031$, binomial test, two-tailed). Analyses of individual L2 items are provided in the online supplemental materials (Tables S1–S7). No associations were evident with *any* music variable for *any* L2 ability. In fact, all Bayes factors (except one) were below 1.00. (The exception, between L2 Accent and Emotions, was nonsignificant, $r = .157$, $p = .055$, $BF_{10} = 1.66$). Because one participant's L2 ability was more than three *SD*s below the mean, we re-ran the main analyses with this outlier removed. The results did not change (Table S8 in the online supplemental materials).

Discussion

We asked whether musical expertise predicted L2 proficiency among Portuguese-speaking adults. In contrast to a previous report

Table 3

Partial Correlations (Pearson and Bayes Factors) Between Musical Ability Measured Objectively with the MET, and Self-Reports Measured with the Gold-MSI (Gender, Education, and Cognitive Ability Held Constant)

	MET melody			MET rhythm		
Gold-MSI variable	*r*	*p*	BF_{10}	*r*	*p*	BF_{10}
		Gold-MSI				
Active engagement	.081	.339	0.427	.213	.010	5.89
Perceptual abilities	.270	.001	33.7	.244	.003	15.3
Music training	.395	<.001	>100	.219	.008	7.09
Singing abilities	.250	.003	16.4	.220	.008	7.31
Emotions	.164	.052	1.68	.139	.096	1.03
General factor	.335	<.001	>100	.258	.002	25.1
Years of music lessons	.309	<.001	>100	.201	.015	4.17

Note. Gold-MSI = Goldsmiths Musical Sophistication Index; MET = musical ear test.

Table 4

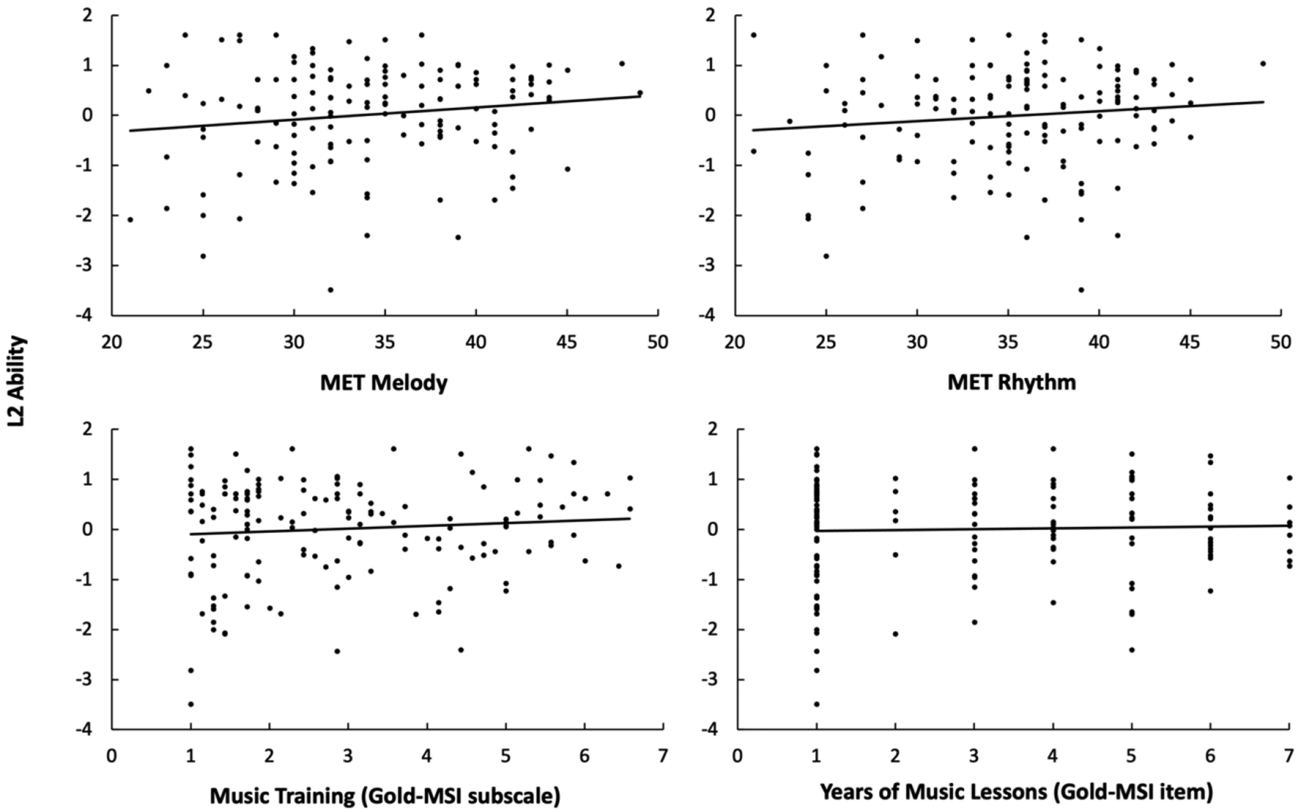
Partial Correlations (Pearson and Bayes Factors) Between L2 Ability and Musical Ability (Gender, Education, and Cognitive Ability Held Constant)

Musical ability variable	*r*	*p*	BF_{10}
	MET		
Melody	.066	.440	0.410
Rhythm	.028	.742	0.328
	Gold-MSI		
Active engagement	.004	.960	0.305
Perceptual abilities	.107	.193	0.650
Music training	.058	.481	0.381
Singing abilities	.063	.445	0.396
Emotions	.101	.216	0.605
General factor	.075	.358	0.445
Years of music lessons	.002	.984	0.305

Note. Gold-MSI = Goldsmiths Musical Sophistication Index; MET = musical ear test.

Figure 2

Scatterplots Illustrating Null Associations Between L2 Ability and the MET Melody Subtest (Upper Left), the MET Rhythm Subtest (Upper Right), the Music Training Subscale from the Gold-MSI (Lower Left), and Years of Music Lessons (Lower Right)



Note. Scores for L2 Ability are standardized ($M = 0$, $SD = 1$).

(Bhatara et al., 2015), there was no association between self-reports of L2 ability and (a) musical ability as measured objectively by the MET, or (b) musical behaviors and experiences as measured by the Gold-MSI. Moreover, for the association between L2 and *rhythm* ability, the data favored the *null* hypothesis, as they did for the association with years of music lessons.

Why do our findings diverge from those of Bhatara et al. (2015)? Although we used the same test of musical ability, we measured L2 proficiency differently. In the earlier study, participants self-reported the number of years they had studied a second language, which provided no guarantee of L2 ability—some participants may have consistently received low grades. By contrast, our participants rated seven different aspects of their English abilities, from which we extracted the common variance to minimize measurement error and maximize construct validity. Future research could test our measure of L2 proficiency in other contexts, along with objective measures of language ability, preferably with repeated administration to document reliability.

Other findings of associations between L2 ability and musical experience could stem from failing to account for general cognitive ability (Bhatara et al., 2015; Li & DeKeyser, 2017) or music training (Coumel et al., 2019; Slevc & Miyake, 2006). Indeed, cognitive ability predicts performance on most tasks (Carroll, 1993; Schellenberg & Weiss, 2013), and music training is an excellent predictor of musical and general cognitive ability (e.g., Correia et al., 2022; Swaminathan et al., 2021). Operational definitions of language ability could also matter, with some but not all aspects of language related to musical ability. In childhood, rhythm ability predicts grammar skills even when general ability is held constant, but the association with phonological awareness disappears (Gordon, Shivers, et al., 2015; Swaminathan & Schellenberg, 2020). Adults and children with good rhythm abilities also exhibit enhanced non-native phoneme discrimination, even after accounting for music training and general ability (Swaminathan & Schellenberg, 2017, 2020). Perhaps rhythm is important early in language (or L2) development and/or when the experimental stimuli are unfamiliar. In any event, the specificity of links between rhythm ability and language remains an open question (Anvari et al., 2002; Swaminathan & Schellenberg, 2020).

For demographics, L2 ability had small associations with gender, education, and cognitive ability. Similar but illusory *male superiority* effects are evident for self-estimates of IQ (Furnham et al., 2005), academic ability (Cooper et al., 2018), job performance (Herbst, 2020), and musical ability (Correia et al., 2023), even though actual ability does not differ between men and women. For education and general ability, positive associations with L2 ability provided evidence for the construct validity of our measure. Additional evidence came from differences among L2 items, which confirmed that self-reported linguistic competence (e.g., comprehension, reading) exceeded performance (e.g., speaking, fluency; Chomsky, 1965).

To conclude, we found no evidence that self-reported language ability relates to musical expertise, including rhythm ability, melody ability, years of music lessons, or music training considered more broadly. In fact, the data corroborated null associations between L2 ability and rhythm abilities, and between L2 ability and years of music lessons. Although our results might reflect how we measured L2 ability, null associations between music and language abilities have important implications for debates on transfer from music to language.

References

Anvari, S. H., Trainor, L. J., Woodside, J., & Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. *Journal of Experimental Child Psychology*, *83*(2), 111–130. https://doi.org/10.1016/S0022-0965(02)00124-8

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

Baumeister, R. F., Vohs, K. D., & Funder, D. C. (2007). Psychology as the science of self-reports and finger movements: Whatever happened to actual behavior? *Perspectives on Psychological Science*, *2*(4), 396–403. https://doi.org/10.1111/j.1745-6916.2007.00051.x

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*(2), 277–282. https://doi.org/10.1037/a0038736

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge University Press.

Chierchia, G., Fuhrmann, D., Knoll, L. J., Pi-Sunyer, B. P., Sakhardande, A. L., & Blakemore, S. (2019). The matrix reasoning item bank (MaRs-IB): Novel, open-access abstract reasoning items for adolescents and adults. *Royal Society Open Science*, *6*(10), Article 190232. https://doi.org/10.1098/rsos.190232

Chomsky, N. (1965). *Aspects of the theory of syntax*. MIT Press.

Cooper, K. M., Krieg, A., & Brownell, S. E. (2018). Who perceives they are smarter? Exploring the influence of student characteristics on student academic self-concept in physiology. *Advances in Physiology Education*, *42*(2), 200–208. https://doi.org/10.1152/advan.00085.2017

Correia, A. I., Lima, C. F., & Schellenberg, E. G. (2023). *Self-awareness of musical ability* (Manuscript submitted for publication).

Correia, A. I., Vincenzi, M., Vanzella, P., Pinheiro, A. P., Lima, C. F., & Schellenberg, E. G. (2022). Can musical ability be tested online? *Behavior Research Methods*, *54*(2), 955–969. https://doi.org/10.3758/s13428-021-01641-2

Coumel, M., Christiner, M., & Reiterer, S. M. (2019). Second language accent faking ability depends on musical abilities, not on working memory. *Frontiers in Psychology*, *10*, Article 257. https://doi.org/10.3389/fpsyg.2019.00257

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Furnham, A., Moutafi, J., & Chamorro-Premuzic, T. (2005). Personality and intelligence: Gender, the Big Five, self-estimated and psychometric intelligence. *International Journal of Selection and Assessment*, *13*(1), 11–24. https://doi.org/10.1111/j.0965-075X.2005.00296.x

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*(1), 16–25. https://doi.org/10.1111/nyas.12683

Gordon, R. L., Shivers, C. M., Wieland, E. A., Kotz, S. A., Yoder, P. J., & McAuley, J. D. (2015). Musical rhythm discrimination explains individual differences in grammar skills in children. *Developmental Science*, *18*(4), 635–644. https://doi.org/10.1111/desc.12230

Goswami, U., Cumming, R., & Wilson, A. (2016). *Rhythmic perception, music and language: A new theoretical framework for understanding and remediating Specific Language Impairment (SLI)*. Nuffield Foundation. https://www.cne.psychol.cam.ac.uk/files/nuffield_briefing_report.pdf

Herbst, T. H. H. (2020). Gender differences in self-perception accuracy: The trust gap and the underrepresentation of women leaders in academia. *SA Journal of Industrial Psychology*, *46*(1), 1–8. https://doi.org/10.4102/sajip.v46i0.1704

JASP Team. (2022). *JASP* (Version 0.16.4) [Computer software]. https://jasp-stats.org/download/

Kaushanskaya, M., Blumenfeld, H. K., & Marian, V. (2020). The Language Experience and Proficiency Questionnaire (LEAP-Q): Ten years later. *Bilingualism: Language and Cognition*, *23*(5), 945–950. https://doi.org/10.1017/S1366728919000038

Kraus, N., & Slater, J. (2016). Beyond words: How humans communicate through sound. *Annual Review of Psychology*, *67*(1), 83–103. https://doi.org/10.1146/annurev-psych-122414-033318

Ladányi, E., Novakovic, M., Boorom, O., Aaron, A. S., Scartozzi, A. C., Gustavson, D. E., Nitin, R., Bamikole, P. O., Vaughan, C., Fromboluti, E. K., Schuele, C. M., Camarata, S. M., McAuley, J. D., & Gordon, R. L. (2023). Using motor tempi to understand rhythm and grammatical skills in developmental language disorder and typical language development. *Neurobiology of Language*, *4*(1), 1–28. https://doi.org/10.1162/nol_a_00082

Law, L. N. C., & Zentner, M. (2012). Assessing musical abilities objectively: Construction and validation of the Profile of Music Perception Skills. *PLoS ONE*, *7*(12), Article e52508. https://doi.org/10.1371/journal.pone.0052508

Lee, M. D., & Wagenmakers, E.-J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge University Press.

Li, M., & DeKeyser, R. (2017). Perception practice, production practice, and musical ability in l2 mandarin tone-word learning. *Studies in Second Language Acquisition*, *39*(4), 593–620. https://doi.org/10.1017/S0272263116000358

Lima, C. F., Correia, A. I., Müllensiefen, D., & Castro, S. L. (2020). Goldsmiths Musical Sophistication Index (Gold-MSI): Portuguese version and associations with socio-demographic factors, personality and music preferences. *Psychology of Music*, *48*(3), 376–388. https://doi.org/10.1177/0305735618801997

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940–967. https://doi.org/10.1044/1092-4388(2007/067)

Milovanov, R., Huotilainen, M., Välimäki, V., Esquef, P. A. A., & Tervaniemi, M. (2008). Musical aptitude and second language pronunciation skills in school-aged children: Neural and behavioral evidence. *Brain Research*, *1194*, 81–89. https://doi.org/10.1016/j.brainres.2007.11.042

Milovanov, R., Pietilä, P., Tervaniemi, M., & Esquef, P. A. A. (2010). Foreign language pronunciation skills and musical aptitude: A study of Finnish adults with higher education. *Learning and Individual Differences*, *20*(1), 56–60. https://doi.org/10.1016/j.lindif.2009.11.003

Milovanov, R., & Tervaniemi, M. (2011). The interplay between musical and linguistic aptitudes: A review. *Frontiers in Psychology*, *2*, Article 321. https://doi.org/10.3389/fpsyg.2011.00321

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). The musicality of non-musicians: An index for assessing musical sophistication in the general population. *PLoS ONE*, *9*(2), Article e89642. https://doi.org/10.1371/journal.pone.0089642

Nayak, S., Coleman, P. L., Ladányi, E., Nitin, R., Gustavson, D. E., Fisher, S. E., Magne, C. L., & Gordon, R. L. (2022). The musical abilities, pleiotropy, language, and environment (MAPLE) framework for understanding musicality-language links across the lifespan. *Neurobiology of Language*, *3*(4), 615–664. https://doi.org/10.1162/nol_a_00079

Neves, L., Correia, A. I., Castro, S. L., Martins, D., & Lima, C. F. (2022). Does music training enhance auditory and linguistic processing? A systematic review and meta-analysis of behavioral and brain evidence. *Neuroscience and Biobehavioral Reviews*, *140*, Article 104777. https://doi.org/10.1016/j.neubiorev.2022.104777

Patel, A. D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology*, *2*, Article 142. https://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. https://doi.org/10.1016/j.heares.2013.08.011

Patel, A. D., & Morgan, E. (2017). Exploring cognitive relations between prediction in language and music. *Cognitive Science*, *41*(52), 303–320. https://doi.org/10.1111/cogs.12411

Posedel, J., Emery, L., Souza, B., & Fountain, C. (2012). Pitch perception, working memory, and second-language phonological production. *Psychology of Music*, *40*(4), 508–517. https://doi.org/10.1177/0305735611415145

Sammler, D., & Elmer, S. (2020). Advances in the neurocognition of music and language. *Brain Sciences*, *10*(8), Article 509. https://doi.org/10.3390/brainsci10080509

Schellenberg, E. G. (2020). Correlation = causation? Music training, psychology, and neuroscience. *Psychology of Aesthetics, Creativity, and the Arts*, *14*(4), 475–480. https://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). Academic Press. https://doi.org/10.1016/B978-0-12-381460-9.00012-2

Shi, L.-F. (2011). How "proficient" is proficient? Subjective proficiency as a predictor of bilingual listeners' recognition of English words. *American Journal of Audiology*, *20*(1), 19–32. https://doi.org/10.1044/1059-0889(2011/10-0013)

Slevc, L. R., & Miyake, A. (2006). Individual differences in second-language proficiency: Does musical ability matter? *Psychological Science*, *17*(8), 675–681. https://doi.org/10.1111/j.1467-9280.2006.01765.x

Swaminathan, S., & Gopinath, J. K. (2013). Music training and second-language English comprehension and vocabulary skills in Indian children. *Psychological Studies*, *58*(2), 164–170. https://doi.org/10.1007/s12646-013-0180-3

Swaminathan, S., Kragness, H. E., & Schellenberg, E. G. (2021). The Musical Ear Test: Norms and correlates from a large sample of Canadian undergraduates. *Behavior Research Methods*, *53*(5), 2007–2024. https://doi.org/10.3758/s13428-020-01528-8

Swaminathan, S., & Schellenberg, E. G. (2017). Musical competence and phoneme perception in a foreign language. *Psychonomic Bulletin & Review*, *24*(6), 1929–1934. https://doi.org/10.3758/s13423-017-1244-5

Swaminathan, S., & Schellenberg, E. G. (2020). Musical ability, music training, and language ability in childhood. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *46*(12), 2340–2348. https://doi.org/10.1037/xlm0000798

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*(6), 992–999. https://doi.org/10.1037/xlm0000493

Talamini, F., Grassi, M., Toffalini, E., Santoni, R., & Carretti, B. (2018). Learning a second language: Can music aptitude or music training have a role? *Learning and Individual Differences*, *64*, 1–7. https://doi.org/10.1016/j.lindif.2018.04.003

Tallal, P., & Gaab, N. (2006). Dynamic auditory processing, musical experience and language development. *Trends in Neurosciences*, *29*(7), 382–390. https://doi.org/10.1016/j.tins.2006.06.003

Tervaniemi, M., Putkinen, V., Nie, P., Wang, C., Du, G., Lu, J., Li, S., Cowley, B. U., Tammi, T., & Tao, S. (2021). Improved auditory function caused by music versus foreign language training at school age: Is there a difference? *Cerebral Cortex*, *32*(1), 63–75. https://doi.org/10.1093/cercor/bhab194

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

Tierney, A., Rosen, S., & Dick, F. (2020). Speech-in-speech perception, nonverbal selective attention, and musical training. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *46*(5), 968–979. https://doi.org/10.1037/xlm0000767

Turker, S., & Reiterer, S. M. (2021). Brain, musicality, and language aptitude: A complex interplay. *Annual Review of Applied Linguistics*, *41*, 95–107. https://doi.org/10.1017/S0267190520000148

Wallentin, M., Nielsen, A. H., Friis-Olivarius, M., Vuust, C., & Vuust, P. (2010). The Musical Ear Test, a new reliable test for measuring musical competence. *Learning and Individual Differences*, *20*(3), 188–196. https://doi.org/10.1016/j.lindif.2010.02.004

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