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Dissecting the Effects of Working Memory, General Fluid Intelligence, and Socioeconomic Status on Musical Sophistication

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Abstract

An increasing amount of literature has sought to clarify many earlier findings between music and intelligence, such as the so-called "Mozart effect". A large portion of this literature has focused on the relationship between musical training and various cognitive measures. Both correlational (Slevc et al., 2016; Talamini et al., 2016; Talamini et al. 2017; Schellenberg, 2006; Degé et al., 2011; Ruthsatz et al., 2008) and experimental studies (Schellenberg, 2004; Moreno et al., 2011) suggest that some sort of relationship exists between music and cognitive abilities. Recent studies, such as Swaminathan et al., 2017, have argued that differences in cognitive ability later in life may be remnants of a selection bias early on where intelligent children who have a high aptitude for music self select into studying music, which is then further confounded by factors such as socioeconomic status. To further investigate this, they found evidence suggesting that musical aptitude is likely a better explanation than musical training for explaining differences in general fluid intelligence. This study seeks to replicate and extend these findings, suggesting that differences in musical aptitude and socioeconomic status can serve as better predictors of individual differences in general fluid intelligence. Whereas the previous study examined how the Musical Ear Test (Wallentin *et al.,* 2010) can predict general fluid intelligence, this study takes a more comprehensive approach, in which the dependent variable is a composite score of general fluid intelligence, and with a measurement of musicality that is arguably more ecologically valid and updated (the melodic memory and beat perception tasks from Goldsmiths Musical Sophistication Index; Müllensiefen *et al.,* 2014).Using these measurements, we were not able to replicate previous findings. General fluid intelligence and working memory capacity were significantly correlated, but neither were predicted by measurements of socioeconomic status. Years of formal training and the measurement of musical sophistication, however, were significantly predictive of both working memory and general fluid intelligence.

Introduction

A great deal of research in recent decades has focused on the relationship between music and intelligence. Most of these studies are correlational (Slevc et al., 2016; Talamini et al., 2016; Talamini et al., 2017; Schellenberg, 2006; Degé et al., 2011; Ruthsatz et al., 2008), but some have involved experimental studies studies as well (Schellenberg, 2004; Moreno et al., 2011). Recently, Swaminathan *et al.* (2017) argued that differences in cognitive ability later in life may be remnants of a selection bias early on where intelligent children who have a high aptitude for music self select into studying music, which is then further confounded by factors such as socioeconomic status. To further investigate this, the authors found evidence suggesting that musical aptitude is likely a better explanation than musical training for explaining differences in general fluid intelligence. Here, we attempt to replicate these findings, and also suggest that differences in musical aptitude and socioeconomic status can serve as better predictors of individual differences in general fluid intelligence. This study uses a number of metrics for musicality, such as the Goldsmiths Musical Sophistication test (specifically, the melodic memory and beat perception tasks)

Methodology

Participants. Two hundred fifty-four students enrolled at Louisiana State University completed the study. We recruited students, mainly in the Department of Psychology and the School of Music. A total of 8 participants were not eligible due to reporting hearing loss, and one individual was greater than 5 SD from the mean age and was removed. Finally, 6 participants were identified as univariate outliers in their performance on the recall portion of at least one of the working memory capacity measures. Thus, 239 participants met the criteria for inclusion. The eligible participants were between the ages of 17 and 38 (M = 20.64, SD = 3.23; 76 males; 1 person did not identify gender). Participants' formal years of musical training was rated on a 9-point likert scale (M = 4.18; SD=2.16) Participants volunteered, received course credit, or were paid $20, and the study was approved by the LSU Institutional Review Board.

Procedure. Participants were asked to perform the Gold-MSI self-report inventory, Tonal span, Symmetry span, Operation span, Gold-MSI beat perception test, Gold-MSI melodic memory test, Gold-MSI sound similarity test, Number Series, and the Raven's Advanced Progressive Matrices (RAPM). The entire experiment lasted roughly 90 minutes in total. Tonal span and sound similarity were not included in the current set of analyses.

Measures

Self-Report Data. In addition to the usual information about demographics, we asked three questions regarding socioeconomic status, similarly to the previous research

(Swaminathan et al., 2017). Specifically, we asked participants to rate their family income, as well as the highest education their father received, and the highest education their mother received, all on a likert scale of 1-9.

Goldsmith's Musical Sophistication Index (Gold-MSI). Participants completed a 38-item self-report inventory and questions consisted of free-response answers or choosing a selection on a Likert scale that ranged from 1-7 (see Müllensiefen et al., 2014).

Symmetry span (SSPAN). Participants completed a two-step symmetry judgment and were prompted to recall a visually-presented red square on a 4 X 4 matrix (Unsworth et al., 2005). In the symmetry judgment, participants were shown an 8 x 8 matrix with random squares filled in black. Participants had to decide if the black squares were symmetrical about the matrix's vertical axis and then click the screen. Next, they were shown a "yes" and "no" box and clicked on the appropriate box. Participants then saw a 4 X 4 matrix for 650 ms with one red square after each symmetry judgment. During square recall, participants recalled the location of each red square by clicking on the appropriate cell in serial order. Participants were provided practice trials to become familiar with the procedure. The test procedure included three trials of each list length (2-5 red squares), totaling 42 squares and 42 symmetry judgments.

Operation span (OSPAN). Participants completed a two-step math operation and then tried to remember a letter (F, H, J, K, L, N, P, Q, R, S, T, or Y) in an alternating sequence (Unsworth et al., 2005). In the math operation, participants saw an arithmetic problem (e.g., (4/4) – 1 = ?) and clicked the screen when they mentally solved the problem. Then, they were presented a digit on the next screen (e.g., 0) and had to click either the "true" or "false" box, depending on whether the presented answer matched the problem on the previous screen. The letter was presented visually for 1000ms after each math operation. During letter recall, participants saw a 4 x 3 matrix of all possible letters, each with its own check box. Letters were recalled in serial order by clicking on each letter's box in the appropriate order. Letter recall was untimed. Participants were provided practice trials, and the test procedure included three trials of each list length (3-7 letters), totaling 75 letters and 75 math operations.

Raven's Advanced Progressive Matrices (RAPM). Participants were presented a 3x3 matrix of geometric patterns with one pattern missing (Raven et al., 1998). Up to eight pattern choices were given at the bottom of the screen. Participants had to click the choice that correctly fit the pattern above. There were three blocks of 12 problems, totaling 36 problems. The items increased in difficulty across each block. A maximum of 5 min was allotted for each block, totaling 15 min. The final score was the total number of correct responses across the three blocks.

Number Series. Participants were shown 15 problems with a maximum time of 4.5 minutes (Thurstone, 1938). They began with four practice problems that were untimed, and were given instructions to solve the next problem by selecting the next number that would complete the series. Following the opportunity to ask any questions, they completed the timed experimental trials. The final score was the number of problems solved within the time limit.

Scores on Raven's Advanced Progressive Matrices and Number Series were converted to z-scores, and were used to assess general fluid intelligence. SSPAN and OSPAN were converted to z-scores as well, and were used as measurements of working memory capacity. The general musical sophistication scores from the Gold-MSI, along with the self-report question from the Gold-MSI about formal years of musical training, were used to assess levels of musical sophistication.

Analysis

Looking only at measurements of general fluid intelligence and musical sophistication, we find a significant – albeit not entirely strong– relationship ($p < .001$; df = 234; $R^2 = .07$). When years of formal musical training is included (with general fluid intelligence being predicted by both musical sophistication and years of formal musical training), however, formal years of musical training was the only significant predictor (see Table 1).

Table 1. Regression model with both general musical sophistication and years of formal musical training as predictors of general fluid intelligence ($p < .001$; df = 234; adjusted $R^2 = .089$).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.2675	0.3454	-3.67	0.0003
GENERAL	0.0092	0.0053	1.75	0.0817
Formal	0.1237	0.0511	2.42	0.0163

In isolation, neither the family income nor the highest education level of mother or father were significant predictors of general fluid intelligence. When included in the larger model that also incorporated years of formal musical training and musical sophistication, they were similarly non-significant (see Table 2). Similarly, Swaminathan, *et al.* (2017), found that mother's education was predictive of music training, but not general fluid intelligence.

Table 2. Linear regression model including all variables predicting general fluid intelligence. Note that years of formal training is the only significant predictor.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.4866	0.4320	-3.44	0.0007
GENERAL	0.0088	0.0053	1.66	0.0976
Formal	0.1170	0.0514	2.28	0.0238
familyIncome	-0.0276	0.0371	-0.74	0.4580
highestFather	0.0491	0.0426	1.15	0.2507
highestMother	0.0274	0.0451	0.61	0.5439

A comparison of the models also demonstrates that years of formal training provides a significant improvement in the original model using only musical sophistication. The other metrics of socioeconomic status, however, do not improve the model.

Table 3. ANOVA table comparing the additive linear regression models predicting general fluid intelligence. Model 1 = general musical sophistication; Model 2 adds formal years of musical training; Model 3 adds family income; Model 4 adds highest level of education of the father, and Model 5 adds highest level of education of the mother.

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	234	394.32				
2	233	384.65	1	9.66	5.85	0.0164
3	232	384.56	1	0.09	0.06	0.8108
4	231	380.69	1	3.87	2.34	0.1272
5	230	380.08	1	0.61	0.37	0.5439

Working Memory. General fluid intelligence and working memory often overlap quite a bit with one another, and our results are no different ($t = .005$ $df = 404$, $p = .99$) The results of the combined model, now predicting working memory rather than general fluid intelligence, is nearly identical. As can be seen in Table 4, both musical sophistication and years of formal training are significant predictors, but measurements of socioeconomic status are not (Adjusted $R^2 = .16$; $p < .001$; $df = 234$).

Table 4. Linear regression model including all variables predicting working memory. Note that both the general score of the Goldsmiths musical sophistication index and years of formal training are significant predictors.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.1503	0.2678	-4.30	0.0000
GENERAL	0.0089	0.0033	2.66	0.0085
Formal	0.0827	0.0324	2.56	0.0113
familyIncome	-0.0366	0.0230	-1.59	0.1131
highestFather	0.0446	0.0268	1.66	0.0973
highestMother	0.0018	0.0281	0.06	0.9499

Musical Sophistication. Although we would predict that family income would be predictive of both formal musical training and musical sophistication, we found no significant relationship with either (see Tables 5 and 6).

Table 5. Measurements of socioeconomic status as predictors of musical sophistication. There were no significant relationships.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	80.1783	4.5118	17.77	0.0000
familyIncome	-1.1088	0.5983	-1.85	0.0651
highestFather	0.6278	0.6932	0.91	0.3661
highestMother	0.8015	0.7294	1.10	0.2729

Table 6. Measurements of socioeconomic status as predictors of formal musical training. Again, there were no significant relationships.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.8211	0.4620	8.27	0.0000
familyIncome	-0.1162	0.0613	-1.90	0.0592
highestFather	0.0465	0.0710	0.66	0.5131
highestMother	0.1286	0.0747	1.72	0.0865

Discussion

Interestingly, formal years of musical training seems to covary quite a bit with the Goldsmiths musical sophistication index. Formal training is more predictive of both general fluid intelligence and working memory. The results suggest that measurements of socioeconomic status are not significant predictors of either general fluid intelligence or formal years of music training. This somewhat contradicts previous work on the subject (Swaminathan et al., 2017; although see Slevc et al., 2016 for a different outcome). Future work is needed with a broader sample of participants from a larger range of socioeconomic status before drawing any conclusions, as this sample was drawn from a population of university students.

Conclusion

Musical sophistication, general fluid intelligence, and working memory are all complex, multi-valenced aspects that can often be difficult to assess cleanly. We attempted to replicate previous work on this topic with a large sample of participants from both psychology and music subject pools, but were unable to replicate some previous previous findings (such as mother's education being significantly correlated with music training). Contrary to what we would expect, we found no significant relationships between socioeconomic status and years of formal musical training or musical sophistication.

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