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How Does Music Training Predict Cognitive Abilities?

A Bifactor Approach to Musical Expertise and Intelligence

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Abstract

Many studies have found that variation in music training is associated with intellectual abilities, but research disagrees over whether music education should primarily correlate with general intelligence (*g*) or with specific lower-level cognitive abilities (e.g., fluid reasoning, verbal ability, or spatial reasoning). Past research, however, has not modeled the data in ways that can separate general abilities like *g* from specific abilities. To examine if the associations between music training and intelligence are general, specific, or both, a bifactor modeling approach was applied to data from a sample of 237 young adults who varied substantially in musical expertise. People completed a range of tasks that measured several lower-order abilities: fluid intelligence, crystallized intelligence (vocabulary knowledge), verbal fluency, and auditory discrimination ability. Simple correlations showed that music training correlated with all four lower-order abilities. A bifactor model, however, found that music training had both general (a strong association with *g*: $\beta = .74$ [.50, .98]) and specific (a moderate association with auditory ability: $\beta = .37$ [.08, .67]) relationships. The findings reconcile past research on the breadth of music training's relationships and illustrate a fruitful method for identifying its links with cognitive abilities.

Keywords: music education; intelligence; bifactor models; auditory discrimination; fluid reasoning; verbal fluency; vocabulary

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Are people with more music training—from lessons, classes, and formal study—smarter? And if they are, in which domains of intelligence are they smarter? Research on the relationships between intellectual abilities and music education has a long history. Studies of "near abilities"—such as how music training correlates with the ability to discriminate musical sounds—go back nearly 100 years to the early development of musical aptitude tests (Seashore, 1919). But studies of "far abilities"—such as how music training correlates with vocabulary size, spatial skills, executive functions, inductive reasoning, and other abilities seemingly remote from what people learn in music education—have attracted attention only recently (Forgeard, Winner, Norton, & Schlaug, 2008; Schellenberg, 2004, 2006).

The generality of music training's relationships with intellectual abilities is controversial. Schellenberg (2006) has argued that music training causes increases in intelligence, and that this effect is primarily general: music training, he proposes, increases *g* much more so than lower-level abilities. Research to date broadly supports this position, although many studies show a range of general and specific effects. In the present research, we present a new analytic approach that can tackle this issue more effectively. Thus far, research has largely used multiple regression methods with observed variables, and such methods can't disentangle the contributions of higher-order abilities (such as *g*) and lower-level abilities (such as fluid reasoning or auditory discrimination ability). As we will show, bifactor latent variable models (Little, 2013; Reise, 2012) can simultaneously estimate higher-order and lower-order relationships, and they thus offer a practical framework for examining whether music training's relationships are general, specific, or both.

Music Training and Intelligence

Research has shown that music training correlates strongly with "near abilities," the cognitive skills targeted during music education. Since the development of music aptitude tests, such as the tests developed by Seashore (Seashore et al., 1939) and Gordon (1965), studies have shown that people with more music training have substantial advantages in tasks that require discerning, reasoning about, and discriminating between pitches, rhythms, and melodies (e.g., Holahan, Saunders, & Goldberg, 2000; Law & Zenter, 2012; Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010). These effects are large, and it seems intuitive that intensive training in music can improve how people process and reason about musical information.

The more controversial claim concerns "far abilities," those skills that are not directly targeted during music education. Schellenberg (2004, 2006) has proposed that music training has broad, general effects that appear in tests of general intelligence. In his intervention experiment, students assigned to music education showed larger gains in full-scale IQ points than students assigned to drama education or to a control group (Schellenberg, 2004). Later correlational studies showed that individual differences in the duration of music training correlated about the same with many domains of intelligence (Schellenberg, 2006). Finding correlations between music training and factors such as fluid reasoning, verbal ability, visuospatial reasoning, and processing speed is intriguing and raises provocative questions about the causal and developmental pathways involved. On the other hand, some studies have found that music training correlates more strongly with some cognitive abilities than others (Degé, Kubicek, & Schwarzer, 2011; Forgeard et al., 2008; Schellenberg, 2011), such as vocabulary size and inductive reasoning but not visuospatial skills. On the whole, the literature on far transfer is controversial, and a recent review concluded future research should examine the cognitive constructs at a finer, more differentiated level of detail (Jaschke, Eggermont, Honing, & Scherder, 2013).

Differentiating Specific and General Effects

The analytic methods used in research to date cannot discriminate between general and specific relationships. The reason is that lower-level cognitive abilities—like vocabulary size, fluid reasoning, and auditory discrimination ability—are themselves substantially correlated. Many theories of intelligence, such as the integrative Cattelll-Horn-Carroll (CHC) approach (McGrew, 2009), contend that lower-order abilities correlate with each other because they share a common cause, such as the higher-order *g* factor. As a result, *g* contributes to variability in lower-order factors like fluid reasoning, verbal ability, and auditory ability, thus complicating the interpretation of simple correlations.

The largest relationships with music training are found for auditory discrimination abilities, a cluster of "near abilities." In the CHC model, these are located within the Gu factor of auditory abilities (Carroll, 1993). Many studies over the years have found that auditory discrimination tasks correlate with general intelligence (e.g., Brown, 1928) and with lower-order abilities such as fluid intelligence (Deary, 1994; Mosing, Pedersen, Madison, & Ullen, 2014), vocabulary size (Horn & Stankov, 1982), and visuospatial ability (Horn & Stankov, 1982). In their twin study, Mosing et al. (2014) found that fluid intelligence and auditory ability had common genetic influences as well as specific ones, consistent with the CHC view of auditory ability as a distinct lower-order ability influenced by *g*.

Because lower-order abilities are strongly influenced by *g*, studies that analyze only the lower-order abilities cannot separate the specific effects of those abilities from the general effects of *g*. In some cases, *g* could be the "third variable" that explains why music training and lower-order ability correlate. For example, a correlation between music training and vocabulary could simply reflect *g*'s relationship with both. The debate over whether music training's correlations with cognitive abilities are primarily general or specific thus cannot be settled with regression

models applied to observed variables, which are poorly suited for disentangling general and specific effects.

Intelligence research, not surprisingly, has grappled with such problems in the past and has some useful analytic tools that can be brought to bear (e.g., Gustafsson, 2001; Kvist & Gustafsson, 2008). Bifactor models, in particular, can separate higher-order and lower-order effects (Chen, Hayes, Carver, Laurenceau, & Zhang, 2012; Little, 2013; Reise, 2012). In a bifactor model, variation in an observed indicator, such as a test of fluid reasoning, is presumed to have three causes: an effect of a higher-order *g* factor, an effect of a lower-order fluid intelligence factor, and residual variance modeled as error. Because the higher-order and lower-order factors are modeled at the same time, researchers can evaluate their relative effects (e.g., which latent variable has a stronger effect on the test) and evaluate if they differentially predict other outcomes.

A bifactor approach can thus shed light on the problem of whether music training's relationships with intelligence are primarily general or specific. To do so, one would first establish a bifactor structure of cognitive abilities, including near abilities (e.g., auditory discrimination) and far abilities (e.g., fluid intelligence and verbal ability). Music training could then be included in the model, and its relationships with both *g* and the lower-order abilities can be assessed at the same time. One virtue of a bifactor approach is that it recognizes the possibility of both general and specific effects. Music training could conceivably predict *g* and several specific abilities, but such a pattern cannot be discerned using regression models with observed variables.

The Present Research

In the present research, we applied bifactor models to the problem of how music training predicts cognitive abilities. We recruited a sample of young adults that varied substantially in music training, from true novices to accomplished performers. People completed a wide range of

cognitive tasks: the near ability of auditory discrimination ability, and far abilities of fluid intelligence (Gf), crystallized intelligence (Gc), and verbal fluency (broad retrieval ability; Gr). A bifactor model was used to simultaneously estimate the general *g* factor and the four specific Gf, Gc, Gr, and auditory factors. This design allows us to evaluate if music training's relationship with intelligence is primarily general (i.e., it correlates with *g* but not with the four specific abilities), primarily specific (i.e., it correlates with at least one specific ability but not with *g*), or both (i.e., it correlates with *g* and with at least one specific ability).

Method

Participants

A total of 265 young adults at the University of North Carolina at Greensboro (UNCG) volunteered to participate. Nearly all of them (n = 255) participated as part of a research option in a psychology course. Ten additional participants were recruited because they were students enrolled in a graduate or undergraduate degree program in music (e.g., music performance, education, theory, or composition); they received $8 USD.

Several participants from the full sample were dropped prior to analysis. Participants who indicated that their native language was not English or Spanish (n = 15) were omitted because of the study's substantial verbal emphasis (i.e., measures of English vocabulary and verbal fluency). We then applied checks for inattentive and careless responding (Meade & Craig, 2012) that have fared well in our past work (see McKibben & Silvia, in press). Two directed response items—items that instruct participants to check a particular scale response—were embedded in the self-report items. We also included the Attentive Responding Scale, a set of 12 paired items (Maniaci & Rogge, 2014). People completed 6 at the start of the study and a nearly identical pair of 6 at the end, and the summed absolute deviation between the pairs was computed. Maniaci and Rogge's (2014) work suggested using a cut-off of 6.5. Thirteen participants were omitted because they

missed both directed response items, had an ARS score of 7 or higher, told the experimenter that they responded carelessly, or showed odd behavior during the study (e.g., falling asleep or compulsive giggling).

The final sample (n = 237) was primarily female (77%, n = 182) and young (M age = 19.08 years, SD = 2.75, Mdn = 18, Min/Max = 18, 40). According to self-reported racial and ethnic identification, the sample was 41% African American, 4% Asian American or Pacific Islander, 54% European American, 8% Hispanic or Latino/a, and 4% Native American; people could select more than one option or decline to select any. Around 8% of the sample majored in music (n = 18). A subset of the sample (n = 183) provided data reported in an earlier article on personality and auditory discrimination ability (Thomas, Silvia, Nusbaum, Beaty, & Hodges, in press).

Procedure

The research project was approved by the UNCG Institutional Review Board (Study #14-0002). The participants took part in group sessions that ranged from 1 to 8 people. The study was programmed and delivered using MediaLab 2012. After completing a consent form and hearing an overview of the study, people completed a series of cognitive tasks and self-report scales. The session lasted approximately 50 minutes.

Fluid intelligence (Gf). We measured fluid intelligence with four tasks. A *letter sets* task presented 5 sets of 4 letters, and people had to identify the set that violated a rule followed by the other 4 sets (15 items, 4 minutes; Ekstrom, French, Harman, & Dermen, 1976). A *number series* task presented a series of digits, and people had to discern the rule governing the series to indicate the number that would come next (15 items, 5 minutes; Thurstone, 1938). A *series completion* task presented a set of visual patterns that developed according to a rule, and people had to indicate which pattern would come next by discerning the rule (13 items, 3 minutes; Cattell & Cattell, 1961/2008). Finally, a *paper folding* task presented images of a sheet of paper being

folded and punched with holes, and people had to identify what the paper would look like when unfolded (10 items, 3 minutes; Ekstrom et al., 1976). All of these tasks have been used in our recent research (Beaty & Silvia, 2012, 2013; Nusbaum & Silvia, 2011a; Nusbaum, Silvia, & Beaty, 2014; Silvia & Beaty, 2012).

Broad retrieval ability (Gr). Broad retrieval ability (Gr) was measured with three verbal fluency tasks used in our past work (Silvia, Beaty, & Nusbaum, 2013): listing words that start with *M*, synonyms for *hot*, and *animals*. People were given 60 seconds for each task. The tasks were scored for the total number of words after excluding repetitions, plurals, and irrelevant responses.

Vocabulary (Gc). We measured crystallized intelligence (Gc) using an Extended Range Vocabulary Test (24 items) and an Advanced Vocabulary Test (18 items; Ekstrom et al., 1976). Participants had 8 minutes to complete both tests. Each test presented a word, and participants had to select a word or phrase that had the same or nearly the same meaning.

Auditory discrimination ability. We measured auditory discrimination ability with the *Musical Ear Test* (MET; Wallentin et al., 2010). The MET has two sections: melody and rhythm. Each section presents short recorded pairs of musical patterns using a piano (melody) or a woodblock (rhythm); half the musical patterns are the same, and half are different. When the pair contains different patterns, there is a single violation. We used an abbreviated version of the MET in which people were presented 80 items—40 for melody ($\alpha = .70$), 40 for rhythm ($\alpha = .59$). After listening to each sound pair (on over-ear headphones at a volume level that the participants could control), people indicated whether the patterns were *same* or *different*; chance performance was 50%. The order of the rhythm and melody sections was counterbalanced across participants, and the software recorded response times to detect if participants responded before the item finished playing. Each item's duration was roughly 8 seconds, so MET scores were treated as missing for anyone who had an average response time of 7 seconds or less.

Music training. Music training was measured by assessing experience with formal music education, as in past research (e.g., Krause, North, & Hewitt, 2015). First, we assessed the number of college-level classes in music participants had taken. As expected, given the sampling of undergraduate and graduate music students, the range was large (0 to 70). We thus treated the number of classes as a censored variable (Long, 1997): all scores of 10 or more were set to 10. Most of the sample had taken no classes related to music (n = 166, 70%); around 7% (n = 17) had taken 5 or more classes. Second, we assessed whether people played a musical instrument proficiently (scored 0 = *no*, 1 = *yes*). Around 30% of the sample (n = 70) reported playing an instrument. The range of music training was thus large in the sample.

Results

Data Reduction and Screening

Table 1 shows the descriptive statistics for the tasks. All models were estimated in Mplus 7.3 using maximum likelihood with robust standard errors. Confidence intervals (95%) are in square brackets.

Evaluating a Bifactor Model of Cognitive Abilities

Before examining how music training predicts cognitive abilities, we first evaluated whether the cognitive abilities formed a coherent bifactor structure. We started by conducting a confirmatory factor analysis of the Gf, Gc, Gr, and auditory factors. For factors with 2 indicators (Gc and auditory ability), we constrained the paths to the indicators to be equal. All factor variances were fixed to 1. The model fit was good: $\chi^2(40) = 65.611$, $p = .007$, CFI = .941, RMSEA = .052 [90% CI: .028, .074], SRMR = .047. Figure 1 illustrates the model; Table 2 displays the correlations between the abilities. The factor correlations were all positive and consistent with a shared higher-order *g*, but not so high that the lower-order abilities appear redundant.

A bifactor model was thus estimated next. In this model, the indicators were predicted by a higher-order *g* factor and by their specific ability factors. The correlations between specific factors, and between the general factor and the specific factors, are fixed to zero in a bifactor model (Little, 2013; Reise, 2012). For specific factors with two indicators, the paths from the specific factor to the indicators were constrained to equal each other. The model fit was good: $\chi^2(35) = 62.981$, $p = .003$, CFI = .936, RMSEA = .058 [90% CI: .034, .081], SRMR = .043.

Figure 2 depicts the bifactor model. A clear bifactor structure emerged: both the higher-order *g* factor and the specific ability factors had notable effects on the indicators.

Music Training and Cognitive Abilities

Because a bifactor model of cognitive abilities represented the data, we next turned to examining how music training predicted cognitive abilities. As noted earlier, a bifactor approach allows for simultaneously estimating relationships with a higher-order *g* as well as with lower-order abilities, so it is well suited to examining the generality or specificity of music training's relationships. Music training was modeled as a latent variable with two indicators: whether people played an instrument (binary), and the number of music classes people had taken (censored).

We started by examining the correlations between the latent music training variable and the four specific ability factors. As Table 2 shows, music training correlated with each of the specific cognitive abilities. The largest correlation was between music training and auditory discrimination ability, $r = .74$ [.56, .91], consistent with much past research.

We then included music training in the bifactor model described earlier. Music training was specified as an outcome, and the predictors were *g* and the specific Gf, Gc, Gr, and auditory factors. The model and results are shown in Figure 3. The bifactor structure indicated that music training's relationships with the lower-order factors were largely due to its relationship with *g*.

The effect of *g* on music training was substantial, β = .74 [.50, .98], $p < .001$. Of the specific factors, only auditory ability had a significant positive relationship with music training, β = .37 [.08, .67], $p = .014$. Most of the lower-order abilities had smaller effects in the negative direction. Both Gf (β = -.18 [-.39, .03], $p = .100$) and Gc (β = -.15 [-.48, .17], $p = .348$) had non-significant negative effects, and Gr had a significant negative effect, β = -.30 [-.55, -.05], $p = .019$. The findings thus suggest that music training's positive relationship with auditory ability is both general (via higher *g*) and specific (via higher auditory discrimination ability).

Discussion

Recent research suggests that variation in music education is correlated with cognitive abilities: people with more music training perform better on a range of cognitive tasks (Schellenberg, 2006, 2011). The scope of these relationships, however, is controversial, particularly for relationships with outcomes that are far from the skills trained in music education. The present research illustrated how bifactor latent variable models can inform the controversy over the generality of music training's relationships with intellectual factors. When the simple correlations between music training and lower-order abilities were estimated, music training correlated with all four lower-level abilities. But when a bifactor structure was specified, music training had a large association with a *g* and a medium association with auditory ability. This pattern reveals that the simple correlations between music training and some of the factors (i.e., fluid and crystallized intelligence) were spurious and due to the shared association with *g*.

The present findings thus extend and reconcile past research. On the one hand, we found support for Schellenberg's (2006) contention that music training is primarily associated with general intelligence: the relation between music training and *g* was the largest effect in the bifactor model (see Figure 3). On the other hand, music training was also specifically related to

auditory discrimination ability, which is consistent with the large literature on music education and auditory abilities.

Our study is agnostic about the direction of the causal paths, and we've sought to avoid implying any particular causal direction. The small body of intervention studies (e.g., Moreno et al., 2011; Schellenberg, 2004) suggests that music training can bring about increased intelligence. Other research shows that intelligence predicts musical achievement (Ruthsatz, Detterman, Griscom, & Cirullo, 2008), a complex finding in itself. Higher intelligence makes it easier for people to master abstract knowledge and complex skills needed to advance in music, such as sight reading (Meinz & Hambrick, 2010). Moreover, access to institutions that can accelerate one's musical skill (e.g., a university music program) will indirectly select for intelligence inasmuch as standardized test scores are considered in admissions. And finally, many other variables influence both intelligence and musical interest. Openness to experience, for example, strongly predicts engagement with music (Beaty et al., 2013; Chamorro-Premuzic & Furnham, 2007; Corrigall, Schellenberg, & Misura, 2013; Greenberg, Müllensiefen, Lamb, & Rentfrow, 2015; Nusbaum & Silvia, 2011b), and it also prospectively predicts the growth of intelligence via the heightened novelty seeking and love of learning typical of high Openness (Raine, Reynolds, Venables, & Mednick, 2002; Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012). Likewise, the growing interest in biological approaches to music and intelligence suggests complex roles for genetics in the overlap and development of music musical ability (Mosing et al., 2014; Mosing, Madison, Pedersen, & Ullén, in press; Schellenberg, 2015).

The present findings offer good support for the CHC approach to auditory discrimination ability. As Carroll (1993) noted, auditory abilities have attracted relatively little attention, and fairly few studies have assessed them alongside many other CHC factors (see Horn & Stankov, 1982; Stankov, 1978). The present findings are consistent with Carroll's conception of auditory

abilities as a distinct factor, and the high correlation of MET scores with seemingly different abilities—such as vocabulary knowledge and verbal fluency—is consistent with a shared influence of a higher-order factor such as *g*. One open question for future research is the specificity of musical information for relationships involving auditory discrimination ability and other cognitive abilities. Carroll speculated that tasks involving musical content might form a distinct facet, compared to tasks using non-musical stimuli. This topic hasn't attracted much attention, although studies that have included musical and non-musical tasks often find that they are only modestly correlated (Law & Zentner, 2012). Future studies on music training and auditory abilities should examine a broad range of auditory tasks to clarify how specific the effects of training might be.

Similarly, future research should examine an expanded range of cognitive outcomes. We agree with Jaschke et al.'s (2013) conclusion that research should examine cognitive constructs at a finer level of detail. The present study examined several of the better-known CHC factors, but many interesting abilities were omitted. The Gf factor, for example, was predominantly inductive reasoning; quantitative reasoning, another major component of Gf (Carroll, 1993), wasn't represented. Likewise, visuospatial abilities, known as Vz in the CHC model, were not included as a distinct factor. Finally, research has found interesting effects for executive functions (Degé et al., 2011), which weren't included here. The methodological strategy developed in the resent research should prove fruitful for future studies that seek to illuminate both higher-order and lower-order effects.

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Table 1

Descriptive Statistics

Variable	*M*	*SD*	*Min, Max*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. MET Melody	26.03	4.52	14, 40	1												
2. MET Rhythm	27.31	4.18	16, 38	.57	1											
3. Gf: Letter Sets	7.33	2.34	1, 13	.14	.19	1										
4. Gf: Number Series	8.24	2.63	1, 15	.05	.09	.37	1									
5. Gf: Series Completion	7.72	1.65	3, 12	.16	.10	.31	.35	1								
6. Gf: Paper Folding	4.90	2.30	0, 10	.22	.09	.39	.32	.40	1							
7. Gr: Letter *M*	14.74	3.53	4, 24	.21	.28	.21	.27	.02	.01	1						
8. Gr: *Hot* Synonyms	5.63	2.56	1, 18	.18	.13	.09	.13	.08	.10	.27	1					
9. Gr: Animals	17.29	3.97	7, 33	.21	.21	.07	.14	.06	.18	.35	.44	1				
10. Gc: Extended Vocab	9.76	3.21	2, 20	.23	.23	.17	.11	.07	.20	.13	.25	.29	1			
11. Gc: Advanced Vocab	7.51	2.51	2, 16	.22	.21	.28	.21	.07	.20	.12	.22	.22	.42	1		
12. Music Classes	1.00	2.47	0, 10	.48	.37	.13	.10	.06	.14	.17	.18	.14	.20	.28	1	
13. Play an Instrument	.30	—	0, 1	.34	.25	.09	.09	-.04	.04	.14	.05	-.02	.13	.13	.40	1

Note. *n* = 237. “Music Classes” is censored at a ceiling of 10. “Play an Instrument” is a binary variable (0 = *no*, 1 = *yes*). Researchers interested in running their own analyses can obtain the raw data and Mplus input files from the first author.

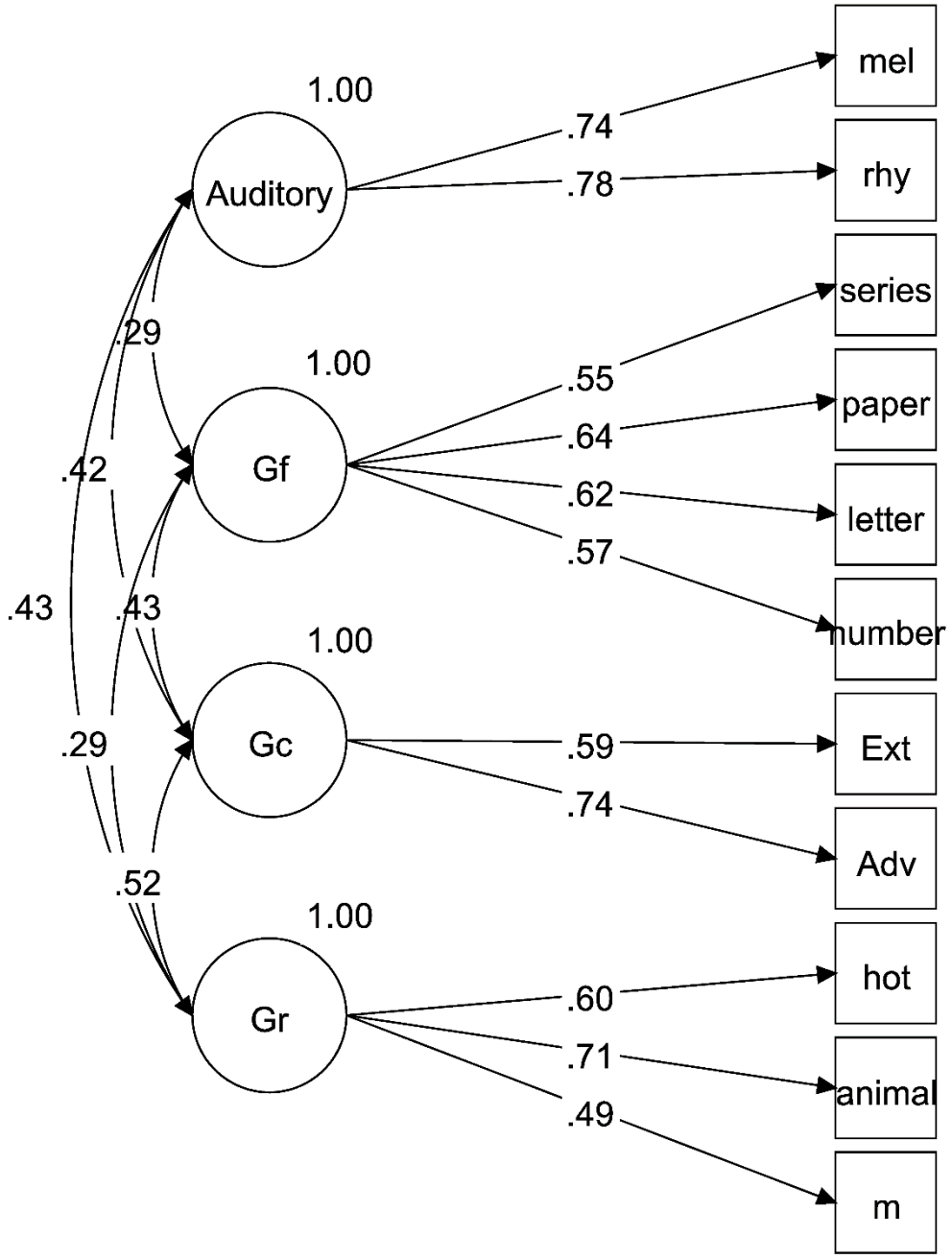
Table 2

Correlations Between Music Training and the Gf, Gr, Gc, and Auditory Ability Factors

	1.	2.	3.	4.	5.
1. Auditory Ability	1				
2. Fluid Intelligence (Gf)	.29 [.13, .45]	1			
3. Crystallized Intelligence (Gc)	.42 [.24, .60]	.43 [.24,.61]	1		
4. Broad Retrieval Ability (Gr)	.43 [.23, .62]	.29 [.09, .49]	.52 [.30, .74]	1	
5. Music Training	.74 [.56, .91]	.23 [.06, .40]	.46 [.23, .69]	.28 [.05, .51]	1

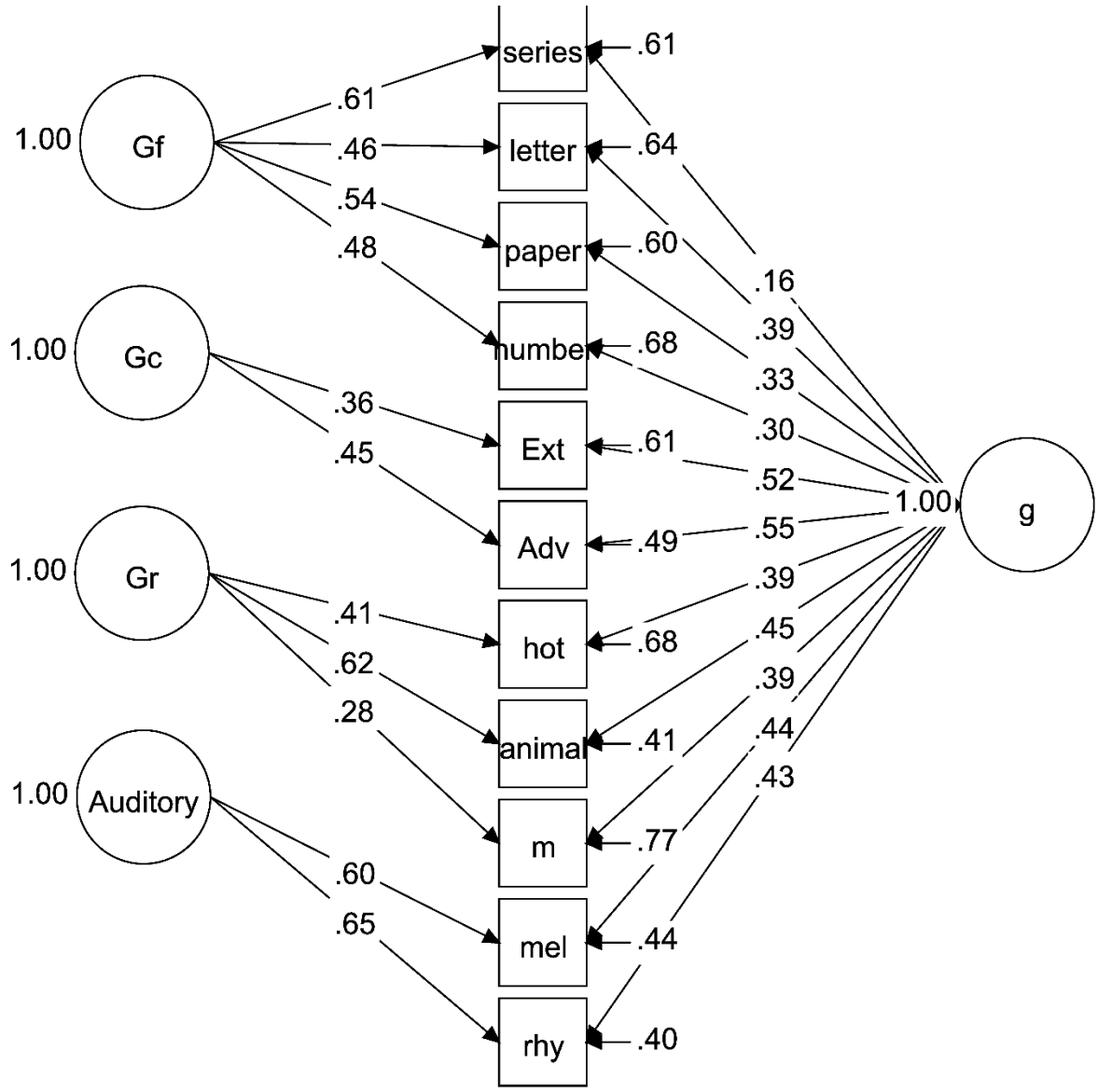
Note. *n* = 237. The coefficients are standardized correlations between the latent variables. Confidence intervals (95%) are in brackets.

Figure 1. A confirmatory factor analysis of Gf, Gc, Gr, and auditory ability.



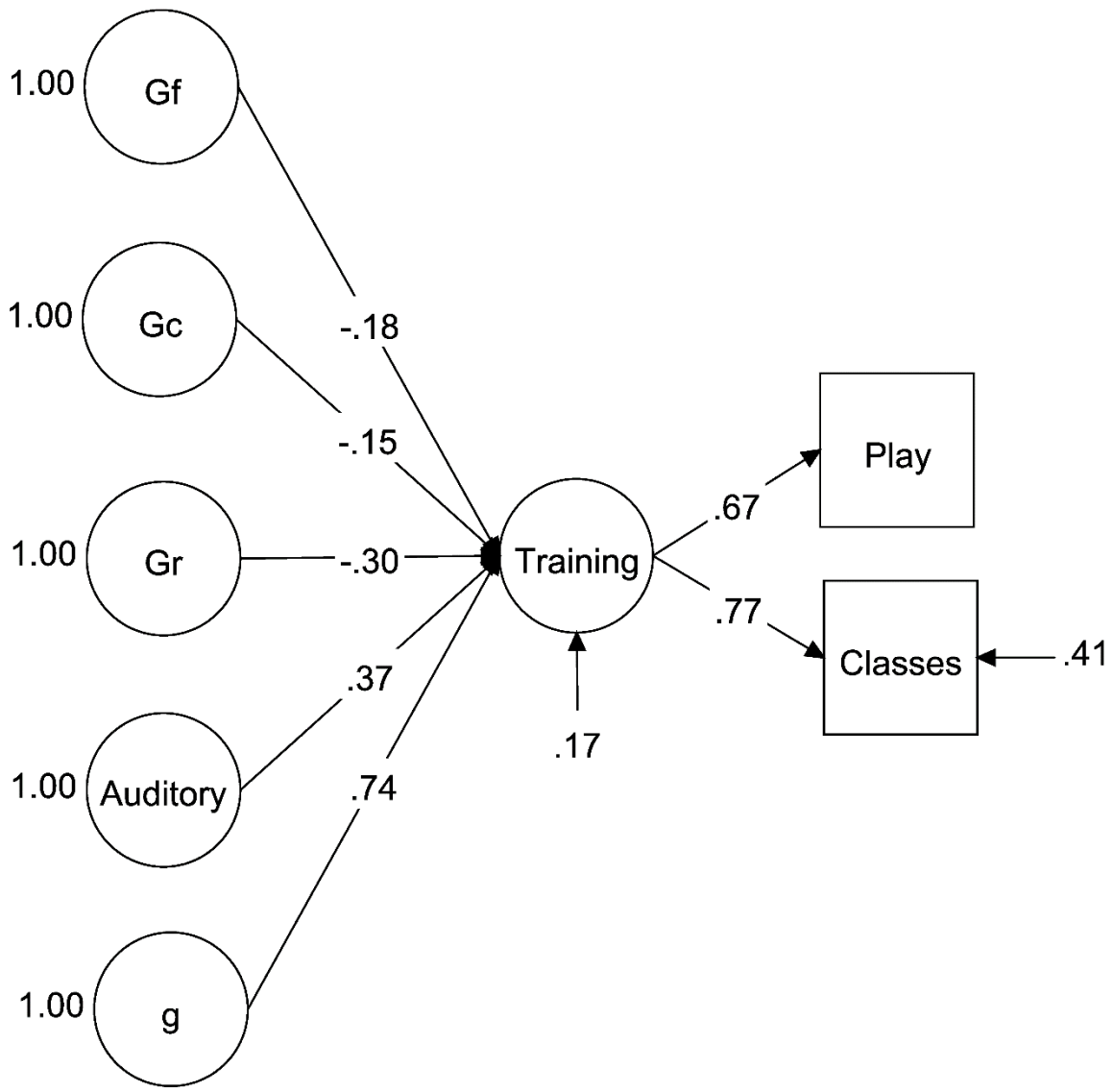
Note. *n* = 237. The regression weights are standardized.

Figure 2. A bifactor model of the higher-order effects of *g* and the lower-order effects of Gf, Gc, Gr, and auditory ability.



Note. *n* = 237. The regression weights are standardized.

Figure 3. How *g* and the lower-order abilities (Gf, Gc, Gr, and auditory ability) predict music training.



Note. *n* = 237. The regression weights are standardized. For clarity, the indicators are omitted; the cognitive abilities are specified as shown in Figure 2.