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Authors

Sala, Giovanni
Gobet, Fernand

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Elvis Has Left the Building: Correlational but Not Causal Relationship between Music Skill and Cognitive and Academic Ability

Giovanni Sala (sala.giovanni475@gmail.com)
Graduate School of Human Sciences, Yamada-Oka 1-2 Suita,
Osaka University, 565-0871, Japan

Fernand Gobet (fgobet@liv.ac.uk)
Department of Psychological Sciences, Bedford Street South,
University of Liverpool, L69 7ZA, United Kingdom

Abstract

Music training is commonly thought to have a positive impact on children's cognitive skills and academic achievement. This belief relies on the idea that engaging in an intellectually demanding activity helps to foster overall cognitive function. We here present a meta-analysis of music-intervention studies in children (N = 3,780, k = 204, m = 43). Consistent with the substantial findings in the field of cognitive training, the overall effect size was small ($\bar{g}$ = 0.117, p < .001). Moreover, when active controls were implemented, the effect was practically null ($\bar{g}$ = 0.032, p = .477) and highly homogeneous (ω^2 = 0.000 and τ^2 = 0.000). Finally, we observe that several independent research groups have concluded, via different methodologies, that music skills acquired by training do not generalize to non-music skills. Thorndike and Woodworth's (1901) common elements theory finds thus further support.

Keywords: music; cognitive training; meta-analysis; transfer of skills.

Introduction

Many parents encourage their children to play a musical instrument. Their hopes sometimes go beyond proficiency in playing music: they enroll their children in violin or piano lessons not only to nurture their musical talent but also because they assume that music training will help their children to get better at school or even become more intelligent.

The idea that learning how to play an instrument improves one's cognitive abilities and academic achievement is popular. Music ability is often associated with talent and superior cognitive skills. Blogs and newspapers often report enthusiastically on the benefits of music for the intellect (e.g., Jaušovec & Pahor, 2017). Even the popular TV series *The Simpsons* has echoed this common belief by defining musical instruments as "the way to encourage a gifted child."

The conviction that music training enhances cognitive ability and academic achievement relies on the assumption that music skills acquired by training can generalize to non-music domains. However, what does the scientific research in the field tell us about music training? Is this assumption correct?

Why Should Music Training Enhance Cognition?

As just mentioned, music training has been claimed to improve a broad range of cognitive and academic skills. However, how is music training supposed to provide such diverse benefits? The standard hypothesis relies on the idea that it is possible to train domain-general cognitive abilities by engaging in intellectually demanding activities. Learning how to play a musical instrument engages executive functions such as cognitive control and working memory (Bialystok & Depape, 2009). In addition, music training requires focused attention and learning complex visual patterns. Schellenberg (2006) has thus proposed that the most likely explanation for the presumed broad set of benefits provided by music training is that it enhances individuals' overall cognitive function and general intelligence. These cognitive skills are major predictors of academic achievement (e.g., Deary et al., 2007), and it might be the case that some domain-specific abilities acquired by music training generalize to other non-music skills.

One further theoretical foundation for the hypothesis according to which music training exerts a positive influence on overall cognitive ability is neural plasticity. Neural plasticity is the ability of the neural system to modify and adapt under the pressure of the environment (Strobach & Karbach, 2016). In turn, the changes in the neural system are supposed to account for improvements in cognitive tests. In fact, musicians do exhibit specific anatomical and functional neural patterns. An increased density of gray matter in musicians has been observed in areas involved in cognitive skills such as auditory localization (right Heschl's gyrus; Bermudez et al., 2009) and language production (Broca's area; Sluming et al., 2002).

With regard to functional differences, expert musicians seem to show, for example, enhanced bilateral activation of the Rolandic operculum (for a review, see Neumann, Lotze, & Eickhoff, 2016). This activation probably reflects superior ability in the processing of auditory information (Koelsch et al., 2006). While there is empirical support for the hypothesis that music training induces significant anatomical and functional changes in the brain, which sometimes lead to unexpected behavioral skill differences (e.g., superior memory for randomized music-related material; Sala &

Gobet, 2017a), the evidence that these neural changes lead to increased cognitive function is much weaker, as discussed in the following sections.

Correlational Evidence

There is strong empirical evidence for a link between superior cognitive ability and musical skill. In a study by Ruthsatz et al. (2008), a group of professional musicians outperformed a group of novices in a standardized measure of fluid intelligence (Raven's Progressive Matrices). Lee, Lu, and Ko (2007) found a correlation between music skill and working memory. In the same vein, Saarikivi et al. (2016) found that neural sound discrimination predicted performance on an inhibition task and a set-shifting task in a sample of children and young adolescents. Finally, Schellenberg (2006) reported positive, yet moderate, correlations between engagement in musical activities and IQ in a group of children and undergraduates. Critically, this positive relationship remained even after controlling for parental income and education.

Music ability correlates with academic skills as well. Anvari et al. (2002) found that music perception skills correlated with reading abilities in preschool children. Similarly, Forgeard et al. (2008) reported that music discrimination skill correlated with phonological processing ability in a group of dyslexic and typically-developing children. In line with these studies, Wetter, Koerner, and Schwaninger (2009) reported a positive relationship between engagement in musical activities and overall academic attainment.

Experimental Evidence and Present Study

As just seen, music skill is positively associated with measures of fluid intelligence, memory, and academic achievement. However, while music skill and cognitive ability are correlated, to date there is no clear evidence of a causal relationship from engagement in music training to superior cognitive function.

A meta-analysis of all the available studies (Sala & Gobet, 2017b) has expressed pessimism about the actual possibility of music-training interventions to enhance children's cognitive and academic skills. All the studies included in this meta-analysis are true experiments: individuals with no (or negligible) music experience are allocated to a music-training group and one or more control groups. This meta-analytic review has found modest or null effects of music training on cognitive abilities such as intelligence, memory, spatial ability, and phonological processing (see also Gordon, Fehd, & McCandliss, 2015). Similar modest or null effects have been found with academic skills such as mathematics and literacy. Furthermore, meta-regression analysis has highlighted that the between-study variability is moderated by the type of control group (active or passive) and the type of allocation to the groups (randomized or nonrandomized). While the studies with no random allocation and passive control groups show some positive effects, when the music-trained groups are randomly allocated and compared to an active control group, the effects are null.

Although Sala and Gobet's (2017b) meta-analytic review suggests pessimism, numerous new experimental studies have been carried out in the last three years. Some of these studies have reaffirmed the idea that music training has a positive influence on children's cognitive and academic skills. However, the impact of these new studies on the overall evaluation of the field of music training has not been assessed yet.

The present study intends to update Sala and Gobet's (2017b) meta-analysis and test the recent claims about the presumed cognitive and academic benefits of music training (e.g., Habibi et al., 2018). To achieve this goal, we (a) extend the literature research to the last three years (from January the 1st 2016 to December the 31st 2018), (b) apply a more advanced modeling approach, and (c) provide stricter inclusion criteria to improve, compared to Sala and Gobet (2017b), the average quality of the studies included in the meta-analytic review.

Method

Literature Search

A systematic search strategy was implemented (Moher et al., 2009). Using the following Boolean string search ("music" OR "musical") AND ("training" OR "instruction" OR "education" OR "intervention"), ERIC, Psyc-Info, and ProQuest Dissertation & Theses databases were searched to identify all the potentially relevant studies. In addition, all the studies included in Sala and Gobet (2017b) were reevaluated for inclusion. Also, we e-mailed researchers in the field (n = 8) asking for unpublished studies, clarifications about the study design, and inaccessible data.

Inclusion Criteria

We kept the same inclusion criteria as Sala and Gobet (2017b). The study had to include (a) a cognitively-demanding music-training program (e.g., learning to play instruments, Kodály method,[1] etc.; no correlational studies were included), (b) at least one control group, (c) non-music-related cognitive or academic outcomes,[2] and (d) participants aged between 3 and 16 with no diagnosed clinical condition or previous formal music experience.

In order to improve the overall quality of the reviewed empirical evidence, the present meta-analysis added three more criteria: (e) the article had to report (or the author had to provide) the means and standard deviations in order to calculate the effect size and sampling error variance; (f) the participants had to be allocated by the experimenter to a

[1] The Kodály method is a well-known educational protocol that focuses on singing, ear training, and the creative skills of musicianship. For more details, see http://kodaly.org.uk/.

[2] For a discussion about the potential benefits of music instruction on non-cognitive/academic skills, see Aleman et al. (2017).

group (randomly or nonrandomly); that is, they were not allowed to decide to which group (experimental or control) they would be allocated; and (g) the experimental group and the control group had to include comparable populations (e.g., same grade, comparable baseline IQ, etc.). These additional criteria led to the exclusion of eight studies previously included in Sala and Gobet (2017b).

Moderators

We chose (a priori) five potential moderators that were included in the meta-regression analysis:

1. Allocation (dichotomous variable): Whether the children were randomly allocated to the groups;
2. Type of control group (active or passive; dichotomous variable): Whether the WM training-treated group was compared to an alternative activity (e.g., visual arts) or a do-nothing (passive) control group. This moderator was necessary to check for placebo effects;
3. Baseline difference (continuous variable): The standardized mean difference (Hedges's *g*) between the experimental and control groups at baseline.[3] A negative regression coefficient would suggest the presence of some true heterogeneity due to regression to the mean;
4. Age (continuous variable): The age of the participants in years;
5. Outcome Measure (categorical variable): The effect sizes were clustered into four broad categories: non-verbal ability (e.g., reasoning, mathematical, and spatial skills); verbal ability (e.g., vocabulary and reading skills); memory (e.g., digit-span and working-memory tasks); and speed (e.g., processing speed and inhibition tasks).[4] The interrater agreement was perfect ($\kappa = 1$).

Modeling Approach

We extracted the effect sizes for each relevant dependent variable reported in the studies using the formulas provided by Schmidt and Hunter (2015). Several studies presented multiple-group comparisons – for example, between one experimental group and two control groups (one active and one passive), or between two experimental groups and one control group. In these cases, we calculated as many effect sizes as the number of comparisons.

We grouped all the effect sizes from the same study into the same cluster. Then, we employed *robust variance estimation* (RVE; Hedges, Tipton, & Johnson, 2010) to model statistically dependent effect sizes and calculates adjusted (i.e., increased) overall standard errors. Also, RVE provides estimates of within-cluster true (i.e., not due to random error) heterogeneity and between-cluster true heterogeneity (ω^2 and τ^2, respectively). We ran (a) intercept models to calculate overall effect sizes and (b) meta-regression models to assess the amount of true heterogeneity explained by the moderators.

Publication Bias

To control for publication bias, we first merged the effects from the same study with the method designed by Cheung and Chan (2014; individual-samplewise procedure). The method averages the effect sizes from the same cluster (in this case, the study) and calculates a corrected sampling error variance in order not to miscalculate standard errors and true heterogeneity. Then, we ran a random-effect model with the merged effect sizes and applied the trim-and-fill publication-bias detection method (Duval & Tweedie, 2000; estimators *L0*, *R0*, and *Q0*).

Results

The search yielded 2,462 records, of which 72 studies were thoroughly evaluated for inclusion. Forty-three studies, 13 of which not included in Sala and Gobet (2017b), met the inclusion criteria with a total of 204 effect sizes (Sala & Gobet, 2017b, included 118 effect sizes). The total number of participants was 3,780. Three researchers replied to our emails. The supplemental materials including details about the studies, techniques employed, additional analyses, data, and R codes, can be found at this link: https://osf.io/2gce3/.

Main Model

The intercept model did not include any covariate (i.e., moderator). The overall effect size of the RVE intercept model was $\bar{g} = 0.117$, 95% CI [0.063; 0.170], $m = 43$, $k = 204$, $df = 17.25$, $p < .001$, $\omega^2 = 0.010$, $\tau^2 = 0.005$. The overall impact of music-training interventions was thus small ($\bar{g} = 0.117$, 95% CI [0.063; 0.170]), albeit statistically significant ($p < .001$).

After merging the effects from the same cluster (i.e., the study), the results of the random-effect model were very similar: $\bar{g} = 0.140$, 95% CI [0.064; 0.217], $p < .001$, $k = 43$, $\tau^2 = 0.018$. The trim-and-fill analysis indicated some publication bias (estimates ranging between 0.046 and 0.122).

Meta-Regression Analysis

The meta-regression model included the five moderators described in the Method section. Baseline and Type of control group were the only two significant moderators ($p = .019$ and $p = .003$, respectively). These two moderators explained almost all the observed true heterogeneity ($\omega^2 = 0.000$ and $\tau^2 = 0.005$). We also checked all the pairwise comparisons for the outcome measures with the Holm's method (for details, see the supplemental materials). None of the comparisons yielded significant differences (all *p*s $\geq .610$).

Finally, we sorted the effect sizes by the moderator Type of control group. The overall effect size of the RVE model including only passive-control comparisons was $\bar{g} = 0.173$,

[3] Five studies implemented an only-post-test design. In those cases, baseline differences were assumed to be null to keep these studies in the moderator analysis.

[4] A more fine-grained categorization was also analyzed (for details, see supplemental materials).

95% CI [0.094; 0.253], $m = 33$, $k = 112$, $df = 19.02$, $p < .001$, $\omega^2 = 0.008$, $\tau^2 = 0.019$. The overall effect size of the RVE model including only active-control comparisons was $\bar{g} = 0.032$, 95% CI [-0.068; 0.132], $m = 19$, $k = 92$, $df = 7.09$, $p = .477$, $\omega^2 = 0.000$, $\tau^2 = 0.000$. Thus, while a small positive and significant effect was observed when passive controls were implemented, no substantial effect occurred when music-treated subjects were compared to controls involved in other activities (Table 1).

Table 1: Summary of the results.

Sample	$\bar{g}$ [95% CI]	p-value
All	0.117 [0.063; 0.170]	.000
Exp. vs passive	0.173 [0.094; 0.253]	.000
Exp. vs active	0.032 [-0.068; 0.132]	.477

Discussion

The present meta-analysis has aimed to update and check the findings of the most recent and comprehensive meta-analysis about the impact of music instruction on children's non-music-related cognitive and academic skills. It has included new studies and nearly doubled the number of effect sizes compared to Sala and Gobet (2017b). Nonetheless, the results of this meta-analysis confirm most of the findings reported in Sala and Gobet (2017b). Most importantly, when only those designs implementing an active control group are considered, the effect of music training is practically null ($\bar{g} = 0.032$, $p = .477$) and highly consistent ($\omega^2 = 0.000$, $\tau^2 = 0.000$). On the other hand, the comparison between music-trained groups and passive controls yields a minimal overall effect ($\bar{g} = 0.173$, $p < .001$) that is easily accounted for by placebo effects. Therefore, the effects of music training on children's cognitive skills and academic achievement are unspecific. Consistent with this explanation, there were no differences between outcome measures, which suggests that the effects of music training (when any) are unspecific.

Finally, beyond supporting Sala and Gobet's (2017b) findings, this meta-analysis highlights new aspects. First, the lack of randomization does not seem to affect the outcomes. On the other hand, compared to Sala and Gobet (2017b) using more rigorous inclusion criteria (e.g., no studies with self-selected participants) lowers the overall effect size (from 0.173 to 0.117) and, most notably, the amount of true heterogeneity (from $\omega^2 = 0.088$ to $\omega^2 = 0.010$, and from $\tau^2 = 0.023$ to $\tau^2 = 0.005$).[5] Second, regression to the mean appears to explain a significant amount of true heterogeneity. This finding does not imply that baseline differences have affected the overall effects. Rather, it means that some of the observed true heterogeneity is spurious (i.e., due to a statistical artifact).

[5] These statistics were obtained by reanalysing Sala and Gobet's (2017b) original dataset with the same multilevel approach used in the current meta-analysis (i.e., RVE).

Triangulation

Beyond meta-analytic evidence, our findings are supported by substantial research into the field of music cognition using different methodologies. Mosing et al. (2016) have shown that music-trained twins do not have a higher IQ than the relative non-music-trained co-twins. The study thus suggests that the level of IQ is determined, to a significant extent, genetically and that engaging in music has no effect on it. Also, Swaminathan, Schellenberg, and Khalil (2017) have recently shown that music aptitude, but not the amount of music training, predicts intelligence in a sample of adults. The association between intelligence (Raven's progressive matrices) and music training is evident until music aptitude is taken into account and added to the regression model.

Strong support for our conclusions is also provided by the fact that the same pattern of results has been found in other domains, including chess training, working-memory training, and brain training. Expertise in chess has been found to correlate with a broad range of cognitive skills such as fluid intelligence, processing speed, short-term memory, and spatial ability (e.g., Burgoyne et al., 2016). Moreover, expert chess players differ from novices and non-players in terms of neural anatomical and functional patterns (e.g., Bilalić et al., 2010; Hänggi et al., 2014). However, chess training does not seem to trigger any genuine improvement in overall cognitive ability or academic achievement (Sala & Gobet, 2016). Analogously, fluid intelligence and working memory capacity are strongly correlated, yet working memory training exerts no effect on fluid intelligence (e.g., Melby-Lervåg et al., 2016). The absence of far-transfer effects is observed even in the presence of functional neural changes (Clark, Lawlor-Savage, & Goghari, 2017). A similar pattern of results has been reported in brain training as well (for a review, see Simons et al., 2016). This outcome upholds the idea that such neural patterns underlie domain-specific skills (e.g., performance in working-memory tasks) rather than overall cognitive function.

These similarities between the results obtained with training studies in different domains induce further pessimism about the concrete possibility of enhancing domain-general cognitive skills through the engagement in intellectually demanding activities. In brief, the idea of enhancing overall cognitive ability through training appears, to date, scientifically implausible (Sala & Gobet, 2019).

Concerning the observed neural patterns in musicians, understanding their actual significance is essential. It is doubtful that functional changes occurring after a music-training intervention represent domain-general improvements in cognitive function. Instead, it is probable that such neural patterns underlie the enhancement of music-related skills such as pitch discrimination (e.g., Nan et al., 2018). It is thus imperative not to erroneously interpret – as sometimes happens (e.g., Habibi et al., 2016) – that functional neural changes in brain areas involved in domain-general cognitive abilities are evidence of cognitive enhancement. The same applies to anatomical neural changes (e.g., increased density of gray matter). Such patterns frequently observed in professional musicians are most likely neural correlates of their domain-specific expertise rather than superior overall cognitive ability.

Theoretical and Practical Implications

Taken together, the findings of the research into music expertise and music training depict a consistent picture: while a positive relationship between music skill and cognitive ability does exist, the benefits of music training do not go beyond the acquisition of music-related skills. In other words, engaging in music does not make people smarter. Instead, as suggested by the research of Mosing et al. (2016) and Swaminathan et al. (2017), smarter people seem to be more likely to engage and succeed in music.

Two major theoretical implications stem from the above results. First, the lack of generalization of music skills acquired by training provides further corroboration for Thorndike and Woodworth's (1901) common elements theory and theories based on the mechanism of chunking. According to Thorndike and Woodworth's theory, transfer of skills is a function of the extent to which two (or more) domains overlap. Thus, transfer of skill between two (or more) domains only loosely related to each other (i.e., far transfer) hardly occurs. Similarly, chunking and template theories (Chase & Simon, 1973; Gobet & Simon, 1996) predict modest or no transfer across different domains or even subdomains of expertise (for a review, see Gobet, 2016). This is because these theories uphold the idea that skill acquisition is based, to a large extent, on perceptual information (i.e., perceptual chunks and templates), which is hardly transferable across different domains given its highly domain-specific nature. Conversely, theories predicting the generalization of trained skills across different domains (e.g., Strobach & Karbach, 2016) are not supported by these outcomes.

Second, the observed correlation between music skill and cognitive ability, together with the lack of broad cognitive effects following music training, suggests that talent is an essential requisite for achieving expertise in music (Schellenberg, 2015). In line with the conclusions of Macnamara, Hambrick, and Oswald (2014), substantial research into music confirms that the amount of deliberate practice alone cannot account for the individual differences in music expertise.

Beyond theoretical aspects, the obvious practical implication is that music training should not be used as a tool for cognitive enhancement. In fact, music training has failed to offer any specific advantage in terms of both cognitive enhancement and academic achievement. These conclusions are made even stronger if we take into consideration that music training has been found substantially ineffective even at enhancing those skills traditionally believed to be tightly close to music skill, such as phonological processing and literacy (e.g., Kempert et al., 2016).

Recommendations for Future Research and Conclusions

As seen, music training does not affect any non-musical cognitive or academic skills. Importantly, the lack of generalization of music skills acquired by training has been established by different research teams using diverse research methodologies (twin studies, hierarchical multiple regression, and meta-analysis of treatment studies).

We briefly discuss some possible avenues of research. As noted above, the quality of experimental designs is inversely related to the size of the effects of music-training interventions and cognitive-training interventions in general (Moreau, Kirk, & Waldie, 2016). Therefore, future studies should strive for high-quality experimental designs regardless of the particular outcome variables and population under investigation. We thus recommend including both active and passive control groups, random allocation of the participants, pre-, post-, and follow-up assessment, multiple measures of the same constructs, and large samples.

It is worth emphasizing that the findings reported here about the null effects of music training do not imply that music is a worthless activity. Rather, the purpose of this article has been to clarify what are the real effects of music training in order to allow people to make informed decisions. Educators and policymakers should be aware that music training provides no benefits on non-music-related cognitive or academic skills (e.g., Nan et al., 2018). As far as we are concerned, even in the absence of other cognitive or academic benefits, it is worthwhile learning an art present in nearly all the cultures in human history.

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