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Music education and its effect on intellectual abilities in children: a systematic review

Abstract: Far transfer between music education and other cognitive skills, such as academic achievement, has been widely examined. However, the results of studies within similar cognitive domains are found to be inconclusive or contradictory. These differences can be traced back to the analytical methods used, differences in the forms of music education studied and differences in neural activation during the processing of these tasks. In order to gain a better picture of the relationships involved, a literature survey was performed in leading databases, such as PubMed/MedLine, psychINFO, ScienceDirect, Embase, ERIC, ASSIA and Jstor from January 2001 to January 2013. All studies included, concerned the far transfer from music education to other cognitive skills in children aged 4–13 years as compared with controls. These studies were independently selected and their quality was assessed by two authors. This systematic review shows the need to address methodological and analytical questions in greater detail. There is a general need to unify methods used in music education research. Furthermore, the hypothesis that intellectual skills, such as mathematics, reading, writing and intelligence can be divided into sub-functions, needs to be examined as one approach to the problems considered here. When this has been done, detailed analysis of cognitive transfer from music education to other disciplines should become possible.

Keywords: academic achievement; cognitive domain; cognitive functions; music intervention; music transfer.

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Introduction

Academic understanding of the various facets of music as a scientific discipline is increasing and their relationships with other cognitive skills is becoming clearer (Hurwitz et al., 1975; Flohr, 1981). In this context, transfer from music to other fields, such as cognition, is a hot topic of debate (Postman, 1971; Hurwitz et al., 1975; Flohr, 1981; Detterman, 1993; Halpern, 1998; Bruer, 1999; Barnett and Ceci, 2002).

Transfer may be basically divided into near transfer and far transfer (Postman, 1971; Barnett and Ceci, 2002). Near transfer in the domain of music and musicianship relates to fine motor control, the perception of pitch, rhythm, timbre, melody, sound differentiation and creativity. Near transfer is a fairly common phenomenon when students are learning to sing or play an instrument, since all the abovementioned skills are part of musicality in general (Ho et al., 2003; Koutsoupidou and Hargreaves, 2009). In contrast, far transfer effects include the effect of music education on academic achievement in such fields as mathematics (Barnett and Ceci, 2002). Investigation of far transfer has so far left researchers with more questions than answers. Studies over approximately the past 110 years have sometimes confirmed the existence of far transfer and sometimes claimed to disprove it (Judd, 1908; Thorndike and Woodworth, 1901a,b,c; Halpern, 1998; Detterman, 1993). Barnett and Ceci (2002) therefore listed what they saw as the basic ingredients of far transfer, which they claimed were essential for a proper understanding of such a complex phenomenon. They went on to state that far transfer constitutes the ability to use an ability learned in one domain and apply it in another unrelated domain, relying on the "[...] domain in question [... and the] underlying cognitive skill involved in encoding, representing, retrieving, mapping, and transferring prior learning" (Barnett and Ceci, 2002: p. 633). In line with this, several researchers have argued that singing or playing music has the potential to enhance cognitive functions, such as intelligence (Degé and Kubicek, 2011a), mathematical skills (Vaughn, 2000; Hodges and O'Connell 2009), spatial reasoning (Bilhartz et al., 2000; Hetland and Winner, 2004), writing (Anvari et al., 2002), reading (Standley, 2008; Beson et al., 2011; Corrigal and Trainor, 2011) and memory (Chan et al., 1998; Ho et al., 2003). However, the results obtained by different authors are inconsistent. It has been suggested that these inconsistencies might be cleared up, if studies use the same or very similar methods (Pietschnig et al., 2010). It has further been hypothesized that poor understanding of the neural functions associated with far transfer, together with the complexity of far transfer as such, might also help to explain these inconsistencies (Barnett and Ceci, 2002). This approach has, however, not yet been applied consistently (Gromko, 2005; Norton et al., 2005; Forgeard et al., 2008; Moreno et al., 2011a,b). Furthermore, it is not enough to consider far transfer from art or music in general (Gromko, 2005; Southgate and Roscigno, 2009; Moreno et al., 2011a): a distinction should be drawn between active and passive perception of music (Hodges and O'Connell, 2009; Kraus and Chandrasekaran, 2010), or between listening (Rauscher and Shaw, 1998), playing, or singing (Vaughn, 2000). Moreover, cognitive functions are often measured with a focus on different skills within a test battery, such as spatial reasoning and verbal abilities, which are addressed by different sub-tests in the overall measurement of an intelligence quotient. Even though we know today that just listening to music will not make us more intelligent (Črnčec et al., 2006b; Pietschnig et al., 2010) by what has come to be known as the Mozart effect proposed by Rauscher et al. (1993, 1997, 1998), Hetland and Winner (2004) found spatial reasoning and verbal abilities to be improved. By contrast, Pietschnig et al. (2010) showed, by means of a thorough meta-analysis, that no convincing evidence could be found for far transfer from music to spatial reasoning, or for the Mozart effect in general. The contradiction between these elegant findings shows the importance of unified methods and a firm grasp of the concept of far transfer in general in understanding the effects of music education on other cognitive and intellectual abilities.

The present review therefore aims to reflect the variation in published results in the field of music education and the far transfer effect and to show how difficult it is to interpret these results when different methods are used to measure them and their discussion is hampered by the absence of a proper classification of far transfer and the lack of a structured understanding of music and musicality.

Methods

Systematic review

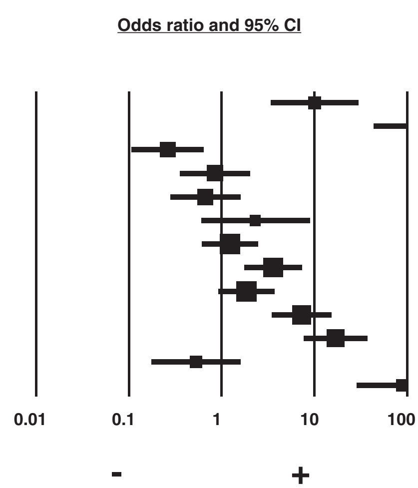
True meta-analysis of far transfer from music education to other cognitive domains is impossible, due to the lack of an adequate structured classification of music and musicality and a lack of understanding of the neuropsychological effects underlying far transfer. We did, nevertheless, carry out a systematic review of the literature; overviews of our findings are given in Figures 1–5.

Studies included and quality assessment

The studies included are shown in Table 1. Their quality was assessed with the aid of a newly developed assessment scale, based on the Newcastle-Ottawa Assessment Scale for meta analyses, used in

Reading

Study name / transfer to	Odds ratio	Lower limit	Upper limit	Z-value	p-value	Relative weight
Register (2001)[a]	10.052	3.337	30.275	4.102	0.000	5.05
Register (2001)[b]	179.419	42.925	749.939	7.112	0.000	3.00
Tsang and Conrad (2011)[a]	0.261	0.105	0.650	-2.887	0.004	7.40
Tsang and Conrad (2011)[c]	0.850	0.352	2.058	-0.359	0.719	7.87
Tsang and Conrad (2011)[b]	0.670	0.276	1.623	-0.888	0.375	7.83
Degé and Schwarzer (2011)[a]	2.319	0.594	9.049	1.211	0.226	3.31
Gromko (2005)[d]	1.238	0.608	2.520	0.588	0.556	12.15
Gromko (2005)[e]	3.579	1.722	7.437	3.417	0.001	11.48
Gromko (2005)[f]	1.860	0.909	3.803	1.700	0.089	12.00
Piro and Ortitz (2009)[c]	7.324	3.441	15.586	5.167	0.000	10.77
Piro and Ortitz (2009)[g]	16.970	7.597	37.907	6.905	0.000	9.51
Jentschke, Koelsch and Friederici (2005)[c]	0.532	0.174	1.629	-1.105	0.269	4.90
Rickard, Bambrick and Gill (2012)[c]	88.906	28.419	278.140	7.712	0.000	4.72



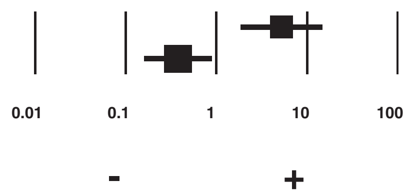
Meta analysis

Figure 1 Study analysis with subdivisions covering: [a]phonological awareness, [b]word decoding and identification, [c]vocabulary, [d]letter, [e]segment, [f]nonsense, [g]verbal sequencing.

Writing

Study name / transfer to	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Register (2001)[a]	5.223	1.816	15.022	3.067	0.002	40.72
Rickard, Bambrick and Gill (2012)[a]	0.378	0.158	0.908	-2.176	0.030	59.28

Statistics for each study; Odds ratio and 95% CI



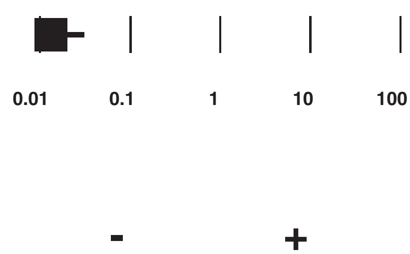
Meta analysis

Figure 2 Study analysis with subdivision covering: [a]logo identification.

Language NOS (not otherwise specified)

Study name / transfer to	Odds ratio	Lower limit	Upper limit	Z-value	p-value	Relative weight
Costa-Giomi (2004)	0.013	0.006	0.031	-9.840	0.000	100.00

Statistics for each study; Odds ratio and 95% CI



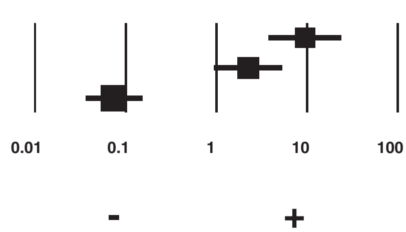
Meta analysis

Figure 3 Study analysis with subdivision covering: language NOS expression.

Mathematics

Study name / transfer to	Odds ratio	Lower limit	Upper limit	Z-value	p-value	Relative weight
Rickard, Bambrick and Gill (2012)[a]	9.429	3.690	24.097	4.687	0.000	26.74
Courey et al. (2012)[b]	2.229	0.921	5.394	1.777	0.076	30.13
Costa -Giomi (2004)[c]	0.074	0.035	0.155	-6.900	0.000	43.14

Statistics for each study; Odds ratio and 95% CI



Meta analysis

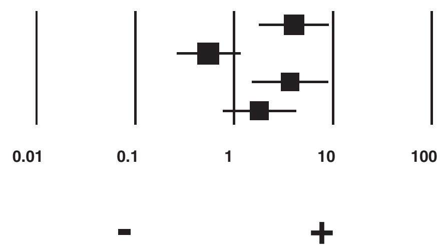
Figure 4 Study analysis with subdivision covering: [a]general skills, [b]fraction calculation, [c]mathematical computation.

IQ

Study name / transfer to	Odds ratio	Lower limit	Upper limit	Z-value	p-value	Relative weight
Portowitz et al. (2009)[a]	4.032	1.770	9.186	3.319	0.001	25.44
Ho, Cheung and Chan (2003)[b]	0.552	0.260	1.174	-1.544	0.123	30.30
Schellenberg (2004)[b]	3.675	1.489	9.068	2.824	0.005	21.14
Rickard, Bambrick and Gill (2012)[b]	1.801	0.759	4.272	1.335	0.182	23.12

Statistics for each study

Odds ratio and 95% CI



Meta analysis

Figure 5 Study analysis with subdivisions covering: [a]Raven's standard matrices, [b]general (non-specified) IQ.

Cochrane reviews (Wells et al., 2011) by two individual researchers (A.C.J. and L.H.P.E.). The clinical music study assessment scale (Musiquas) was developed by the authors, as no assessment scale focusing on music-related studies was already available. This scale assesses the quality of studies to be included in meta-analyses with regard to 27 aspects divided over four main groups: selection, control criteria, exposure and outcome. Musiquas was fine-tuned to permit assessment of the strength of the music studies included in meta-analyses and systematic reviews, to detect possible methodological flaws. Full details of Musiquas are given elsewhere (http://www.academia.edu/2521568/Clinical_music_study_quality_assessment_scale_MUSIQUAS_1st_Edition_).

Time frame

For the purpose of this review, we limited our search to studies published between January 2001 and January 2013. Two authors (A.C.J. and L.H.P.E.) independently inspected titles and abstracts for compliance with the defined inclusion criteria. Studies before 2001 had been covered by meta-analyses by Hetland and Winner (2004) and Pietschnig et al. (2010) and were therefore excluded from our review to avoid publication bias.

Any disagreement was resolved through discussion and/or consultation with another independent researcher.

Classification

Our search for studies to be included in the systematic review revealed five main categories of transfer outcomes from music: reading, spatial reasoning, writing, mathematics and intelligence. We computed individual statistical values for each category. Where certain studies introduced subdivisions of skills within a given cognitive function, such as mathematics, we incorporated these subdivisions in our analysis and calculated individual effect sizes rather than one overall effect. For example, reading was divided into phonological awareness, vocabulary, word decoding and identification and verbal sequencing. This enabled us to draw a more precise picture of the influence of music on transfer outcomes. Although we divided transfer outcomes into the above-mentioned five main groups, we observed an overlap in the investigation of outcomes within the studies included; some studies investigated more than one direct outcome, for example mathematics and intelligence, while others analyzed a whole range of outcomes from mathematics to reading within the same experimental set-up.

As we are mainly interested in far transfer, we did not differentiate between different forms of music education or participation. Although we are aware that there are various forms of music education and that the different forms may have different effects on transfer outcomes, this subdivision would have exceeded the scope of the present review; it may be considered in future research as mentioned in the discussion.

Age of pupils and form of music participation

We focused our analysis on studies, which used randomized controlled trials (RCTs). As there are not many RCT studies, we also included studies that made use of a control group and longitudinal studies, which we define as studies having more than three (T_0–T_2) test moments and/or a length of more than 12 months. To merit inclusion into our analysis, studies had to consider pupils who were between 4 and 13 years old who played a musical instrument and/or sang, and who were usually exposed to music in general, listening to it and learning music theory to help them play an instrument. We have not based our inclusion criteria on length of music education, as again there is a lack of a consensus among researchers on this point.

Exclusion criteria

Studies were excluded when effects were measured on the basis of study sizes rather than sample sizes, when there was no control group, when we were aware that studies based on the same experimental population were published in more than one journal or at different times (leading to the exclusion of spatial reasoning studies),

Table 1 Included studies and quality assessment scores.

Study (publication date)	Musiquas rating	N instruction	N control	(R)CT	Transfer to	Music intervention	Age	Type	Outlet
Degé and Schwarzer (2005)	8	14	14	√	Phonological awareness	Playing	5–6	Study	Frontiers in Psychology
Costa-Giomi (2004)	8	63	54	√	Language expression and mathematical computation	Playing (p)	8–12	Longitudinal study design	Psychology of Music
Ho et al. (2003)	8	45	45	√	IQ	Playing	5–13	Study	Neuropsychology
Piro and Oritz (2009)	7	46	57	√	Reading	Playing (p)	6–8	Study	Psychology of Music
Portowitz et al. (2009)	6	45	36	√	IQ	Playing and general music involvement	7–9	Study	Research Studies in Music Education
Gromko (2005)	4	43	60	√	Reading	General music involvement	4–6	Study	Journal of Research in Music Education
Tsang and Conrad (2011)	7	26	43	√	Reading, (near transfer)	Formal instrumental training	5–9	Study	Music Perception
Schellenberg (2004)	8	32	34	√	IQ	Playing and singing	6	Study	Psychological Science
Register (2001)	5	25	25	√	Reading, writing	General music involvement	4–5	Study	Journal of Music Therapy
Jentschke et al. (2005)	5	21	20	√	Reading	Singing and playing	10–12	Study	NeuroImage
Courey et al. (2012)	6	37	30	√	Mathematics, (near transfer)	Music theory	8–11	Study	Springer Science
Rickard et al. (2012)	7	47	37	√	IQ, writing	Playing	10–13	Study	International Journal of Music Education
	7	38	31	√	Mathematics, reading	Playing	10–13	Study	

when they analyzed near transfer, when they were meta-analyses or longitudinal studies lasting <12 months.

Databases and journals

The online databases PubMed/MedLine, psychINFO, ScienceDirect, Embase, ERIC, ASSIA and Jstor were searched in five main rounds, covering: (1) music, transfer, education, (2) music education, transfer effect, (3) effects of music on education, on transfer, on mathematics, on reading, on writing, on IQ, on memory, (4) music, near transfer, far transfer and (5) music, academic achievement. These main search activities were repeated, adding longitudinal and longitudinal study design to the above-mentioned search terms. Where necessary, the search terms were attuned to the requirements of the databases searched. We further consolidated and expanded our investigation by using the following MeSH terms: music, transfer and education. In addition to the above databases, online editions of Music Psychology, the British Journal of Music Education and the Journal of Experimental Child Psychology were manually examined using the above search and MeSH terms.

Finally, an extensive manual search of printed editions of the Journal of Music Education, Music Perception, Musicae Scientiae and the Journal of Research in Music Education was conducted.

Authors were contacted personally where necessary, to obtain missing information needed to complete the statistical analysis.

Data analyses

Values of the mean (M) and standard deviation (SD) of the effects studied in conjunction with sample sizes of the experimental and control groups were used to gain an insight into the effects described. We also used odds ratios (OR) to estimate the likelihood of the occurrence of a given effect of music on the individual outcomes. Here too, we did not pool the results into one overall effect size, in order to avoid sample size bias and generalization. Nevertheless, we did use standardized mean differences (SMDs), to combine different test results concerning the same outcome.

Results

The search yielded 217 articles, of which 61 were considered as possibly relevant. Twelve studies met all inclusion criteria (see Figure 6 for study flow diagram). Although one review and two meta-analyses have been published in our inclusion timeframe (Hetland and Winner, 2004; Standley, 2008; Pietschnig et al., 2010) only the review by Hetland and Winner (2004) gave an overall insight into music education and the near and far transfer effect, while Pietschnig et al. (2010) focused on the Mozart effect, therefore analyzing the effect sizes based on such categories as ‘overall’ mathematics or ‘overall’ reading abilities, not considering the complexity of far transfer as here hypothesized. Our inclusion of longitudinal studies

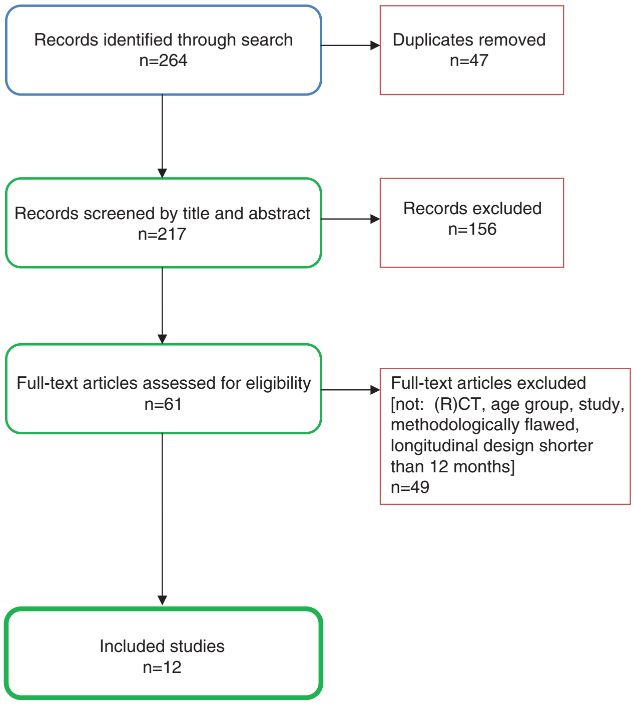


Figure 6 Study flow diagram.

yielded five additional studies that were considered relevant at first sight. On closer investigation, however, four of these studies had to be excluded as: (1) they only considered the effect of music on brain development without taking academic achievement into account, or did not measure the effect of music on academic achievement directly (Scales et al., 2006; Hyde et al., 2009), (2) the age group was outside our inclusion frame (Gruhn, 2002) and (3) the longitudinal study lasted <12 months (Chobert et al., 2012). Hence, only one longitudinal study (Costa-Giomi, 2004) met our inclusion criteria and was included with the other 12 for further analysis.

Reading

Figure 1 shows the OR for studies that mentioned the effect of music education on reading. OR were chosen to indicate the likelihood of a positive or negative outcome. The forest plot shows that most of the studies favor the music intervention groups ('+'). Studies by Tsang and Conrad (2011), Piro and Ortiz (2009), Jentschke et al. (2005) and Rickard et al. (2012) represent the effects on vocabulary in reading. The positive likelihood is close to 0 with $p<0.05$, while the negative likelihood of the effect of music on vocabulary in reading is represented by an OR of 0.532 with a probability of $p=0.279$. A comparable observation can be made concerning measures of phonological awareness (Register, 2001; Tsang and Conrad, 2011; Degé and Schwarzer, 2011b). The results range from 0.261, $p<0.005$ to 10.052, $p<0.001$ yielding both a negative and a positive effect.

Writing

Studies analyzing writing skills yielded contradictory findings. Rickard et al. (2012) have shown a clear negative effect of music on writing, with an OR of 0.378, $p=0.03$ favoring the non-music intervention group (see Figure 2). Register's (2001) data, by contrast, demonstrated a markedly positive effect with a confidence interval of $p<0.01$. The logo identification sub-group was included in both studies, but was more thoroughly analyzed by Rickard et al. (2012).

Language not otherwise specified (NOS)

Costa-Giomi's (2004) findings yielded a negative effect on language expression with $p<0.001$. However, there is no comparable study and the language domain is not further specified.

Mathematics

The analysis of the transfer from music to mathematical skills appears to be the most controversial of all of the fields considered here.

The difficulty of analyzing transfer from music to mathematics is similar to that where reading is involved, as both target domains have to be divided into sub-groupings (Figure 4). Only three studies met our inclusion criteria. While Rickard et al. (2012) and Courey et al. (2012) show a significant positive effect of music on mathematical skills (with $p=0.076$), Costa-Giomi (2004) showed a negative effect on mathematical computation skills ($p<0.001$). These differences in results can possibly be attributed to the use of different study designs as well as differences in the tests administered. Furthermore, each study analyzes a different subdivision of mathematics, which may be another reason for the differences observed.

IQ

The positive effect of music on IQ has been shown in a vast number of publications. Even though different test batteries were administered, the results still tend to produce positive effects. Of the four studies meeting our selection criteria, only one (Ho et al., 2003) failed to show a positive effect. The negative effects reported in this publication may be due to the type of music intervention involved (general arts involvement, listening, playing and/or singing) (Figure 5). By contrast, the study by Schellenberg (2004) showed a positive effect of music on IQ with p=0.005 according to the meta-analysis. Furthermore, this investigation revealed no significant difference between results obtained using general IQ measurements and for example, Raven's standard matrices, general non-specific IQ measurements, or the Wechsler Intelligence Scale for Children 3rd edition (WISC III).

The studies dealing with mathematics, writing and reading yielded surprising results. Rickard et al. (2012) and Courey et al. (2012) analyzed mathematical skills in general and the calculation of fractions in particular, and found a positive transfer effect, while Costa-Giomi (2004) found a negative effect. Studies researching reading and writing have shown both negative and positive far transfer outcomes. The longitudinal study on (NOS) language expression has yielded a negative result. Since, however, there was no other study to compare it with, this only adds to the mystery surrounding far transfer effects.

These results show that subdivision of a cognitive function can strongly influence the likelihood of finding transfer to one function from an activity such as music education.

Discussion

Music and far transfer

> 'Estimation of a single effect size for far transfer is misguided in view of this complexity' (Barnett and Ceci, 2002: p. 612).

Music education requires growing justification amongst policy makers (Branscome, 2012). Adding to this pressure, the far transfer effect remains an unresolved mystery in the realm of music education. Our review, however, sheds light on the possible cause of this mystery, by investigating the need to use more unified methods when analyzing music and far transfer, to move away from the use of umbrella terms and further investigate the neural correlates underlying such transfer effects. In fact, there are many studies analyzing far transfer from music to intelligence. Most of these studies did not meet our inclusion criteria, however. Of the ones that do, that by Ho et al. (2003) failed to show a positive transfer effect while that by Schellenberg (2004) did show a positive transfer effect with two different measures of intelligence: Raven's standard matrices and general (aspecific) intelligence. Here, the two different results can be attributed to a lack of uniformity in the test methods used. While both studies analyze intelligence, Schellenberg (2004) uses an aspecific measure of intelligence, which may have a stronger effect sensitivity in this case and is thus more liable to yield a positive effect. However, Schellenberg's study is known to be problematic, because the non-music drama intervention group was merged with the no-intervention control group before comparison with the music groups. A direct comparison of the drama group with the music group would very likely not have resulted in any significant difference in intelligence.

Music education, far transfer and neurocognitive function

> 'The mind is so specialized into a multitude of independent capacities that we alter human nature only in small spots, and any special school training has a much narrower influence upon the mind [...] than has commonly been supposed' (Thorndike, 1906, pp. 246–247).

Music-making (singing or playing an instrument), activates a vast number of different cerebral regions (Schlaug et al., 1995, 2005; Kraus and Chandrasekaran, 2010; Strait et al., 2011; Kraus et al., 2012). The overlap in the cerebral areas involved in the execution of musical and non-musical tasks means that it is tempting to group them under certain umbrella terms; but as shown in the present review that might be the wrong approach. Intellectual abilities, such as intelligence, mathematics, writing and reading should all be further subdivided. For example, mathematics may be divided as mentioned above into general skills, basic concepts, operations and applications, where each of these functions activates additional/different cerebral areas. These areas are not necessarily active during the execution of the other skills, even though they also fall under the term mathematics (Campbell, 1992). It is then likely that an analysis of general skills will show a positive transfer from music, while a study of specific operations or applications may not. The key question here is to what extent far transfer can be confirmed or denied on the basis of a study of overall skills. As argued by Barnett and Ceci (2002), processing models of far transfer account for differences in the individual processes of domain-related cognitive skills; this supports the idea of dividing academic skills into their consecutive building blocks, such as application, operation and execution in mathematics. The present review has hypothesized that far transfer can only be reliably demonstrated when these subdivisions, both in the execution of cognitive skills and in the analysis of the sub domain of far transfer as proposed by Barnett and Ceci (2002), are taken into account and analyzed individually.

In addition to this subdivision of the skills domains studied and the use of uniform methods to study them, the form of educational music intervention: (1) general music education versus a more specific approach, (2) individual tuition versus group or classroom tuition and (3) the sub-groupings, we propose, is thus important in generating homogeneous test results. The length of intervention should also be taken into consideration, as this may be a strong indicator of an effect or the lack thereof. As most studies have only involved music educational interventions lasting less than a year, we have not included the length of the intervention as a parameter in this review (Bilhartz et al., 2000; Anvari et al., 2002; Ho et al., 2003; Hetland and Winner, 2004; Standley, 2008; Hodges and O'Connell, 2009; Degé and Kubicek, 2011a). However, we suggest that the intervention should last at least a year to be able to show clear results. Although the articles we reviewed made a first attempt to analyze these relationships, they lack more detailed consideration of sub-groupings in the non-music skills acquired and fail to study the effect of a variety of music education approaches using uniform methods and interventions of varying duration. The line of attack we propose can lead to a deeper insight into the nature of music and far transfer and should therefore be considered in future research.

The future directions, of the study of far transfer from music education

Consistent, thorough investigative methods are key in achieving better support for future studies in experimental psychology. This review has shown that a lack of uniform research methods in the study of far transfer from music education makes it difficult to achieve consistent results that can be reliably incorporated into the growing body of knowledge. Research should aim, in future, at more longitudinal studies producing more reliable results, through a thorough testing regime, a consistent research protocol and the long-term research design itself. Direct interaction between practice (music education in this case) and research will enable researchers to achieve this goal. More specifically, use of longitudinal RCTs extending over at least 3 school years, with a significant number of test moments from baseline measurement, paired with a multidisciplinary understanding, will set the tune for the development of a stronger and more unified research method for music education, far transfer and music cognition studies. We therefore argue that the studies considered here yield heterogeneous results, mainly due to the use of umbrella terms. As explained above, we believe that this issue can be resolved through analysis of sub-groups in the realm of cognitive execution of the tasks proposed, as well as a detailed subdivision of far transfer as such. In addition, there is the need for a uniform methodological approach to the analysis of transfer from music to other non-musical abilities.

We are confident that this alternative perspective will provide a basis for more powerful, reliable and accurate study of far transfer from music to a variety of cognitive skills.

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References

Anvari, S.H., Trainor, L.J., Woodside, J., and Levy, B.A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. J. Exp. Child Psychol. *83*, 111–130.

Barnett, S.M. and Ceci S.J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. Psychol. Bull. *128*, 612–637.

Besson, M., Chobert, J., and Marie, C. (2011). Transfer of training between music and speech: Common processing, attention, and memory. Front Psychol. *Vol. 2 / Article 94*, 1–12.

Bilhartz, T.D., Bruhn, R.A., and Olson, J.E. (2000). The effect of early music training on child cognitive development. J. Appl. Dev. Psychol. *20*, 615–636.

Branscome, E.E. (2012). The impact of education reform on music education: Paradigm shifts in music education curriculum, advocacy and philosophy from Sputnik to race to the top. Arts Educ. Policy Rev. *113*, 112–118.

Bruer, J. (1999). The Myth of the First Three Years (New York: Free Press).

Campbell, J.I.D. ed. (1992). The Nature and Origins of Mathematical Skills (Amsterdam: Elsevier Science Publishers B.V.).
Chan, A.S., Ho, Y., and Cheung, M. (1998). Music training improves verbal memory. Nature *396*, 128.
Chobert, J., François, C., Velay, J.-L., and Besson, M. (2012). Twelve months of active musical training in 8- to 10-year-old children enhances the preattentive processing of syllabic duration and voice onset time. Cereb. Cortex, online first 12th December 2012.
Corrigall, K.A. and Trainor, L.J. (2011). Associations between length of music training and reading skills in children. Music Perception *29*, 147–155.
Costa-Giomi, E. (2004). Effects of three years piano instruction on children's academic achievement, school performance and self-esteem. Psychol. Music *32*, 139–152.
Courey, S.J., Balogh, E., Siker, J.R., and Paik, J. (2012). Academic music: music instruction to engage third-grade students in learning basic fraction concepts, educational studies in mathematics, published online/pre print publication 23rd March 2012, pp 1–28.
Črnčec, R., Wilson, S., and Prior, M. (2006a). The cognitive and academic benefits of music to children: facts and fiction. Educ. Psychol. *26*, 579–594.
Črnčec, R., Wilson, S., and Prior, M. (2006b). No evidence for the Mozart effect in children, Music Perception *23*, 305–318.
Degé, F. and Kubicek, C. (2011a). Music lessons and intelligence: a relation mediated by executive functions. Music Perception *29*, 195–201.
Degé, F. and Schwarzer, G. (2011b). The effect of a music program on phonological awareness in oreschoolers. Front. Psychol. *2*, 1–7.
Detterman, D.K. (1993). The case for the prosecution: transfer as an epiphenomenon. In: D.K. Detterman and R.J. Sternberg, eds., Transfer on Trial: Intelligence, Cognition and Instruction. Norwood, NJ: Ablex.
Flohr, J.W. (1981). Short-term musical instruction and young children's developmental musical aptitude. J. Res. Music Educ. *29*, 219–223.
Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning, PLoS ONE open access article, *3*, 1–8.
Gromko, J. (2005). The effect of music instruction on phonemic awareness in beginning readers. J. Res. Music Educ. *53*, 199–209.
Gruhn, W. (2002). Phases and stages in early music learning; A longitudinal study on the development of young children's musical potential. Music Educ. Res. *4*, 51–71.
Halpern, D.F. (1998). Teaching critical thinking for transfer across domains. Am. Psychol. *53*, 449–455.
Hetland, L. and Winner, E. (2004). Cognitive transfer from arts education. In: Eisner, E. and Day, M., eds., Handbook on Research and Policy in Art Education, National Art Education Association, pp 1–67.
Ho, Y.-C., Cheung, M.C., and Chan, A.S. (2003). Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children. Neuropsychologia *17*, 439–450.
Hodges, D.A. and O'Connell, D.S. (2005). The impact of music education on academic achievement. In: S. Hallam, I. Cross and M. Thaut, eds., Oxford Handbook of Music Psychology. Oxford and New York: Oxford University Press, pp. 58–91.
Hurwitz, I., Wolff, P.H., Bortnick, B.D., and Kokas, K. (1975). Nonmusical effects of the Kodaly music curriculum in primary grade children. Journal of Learning Disabilities *8*, 45–51.
Hyde, K.L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A.C., and Schlaug, G. (2009). Musical training shapes structural brain development. J. Neurosci. *29*, 3019–3025.
Jentschke, S., Koelsch, S., and Friederici, A.D. (2005). Investigating the relationships of music and language in children; influences of musical training and language impairment. Ann. N. Y. Acad. Sci. *1060*, 231–242.
Judd, C.H. (1908). The relation of special training to general intelligence. Educ. Rev. *36*, 28–42.
Koelsch, S. (2012). Brain and Music (Oxford: Wiley and Blackwell).
Koutsoupidou, T. and Hargreaves, D.J. (2009). An experimental study of the effects of improvisation on the development of children's creative thinking in music. Psychol. Music *37*, 251–278.
Kraus, N. and Chandrasekaran, B. (2010). Music training for the development of auditory skills. Nat. Rev. Neurosci. *11*, 599–605.
Kraus, N., Strait, D., and Parbery-Clark, A. (2012). Cognitive factors shape brain networks for auditory skills: spotlight on auditory working memory. Ann. N. Y. Acad. Sci. *1252*, 100–107.
Moreno, S., Bialystok, E., Barac, R., Schellenberg, E.G., Cepeda, N.J., and Chau, T. (2011a). Short-term memory training enhances verbal intelligence and executive function. Psychol. Sci. *22*, 1425–1433.
Moreno, S., Friesen, D., and Bialystok, E. (2011b). Effect of music training on promoting preliteracy skills: Preliminary causal evidence. Music Perception *29*, 165–172.
Norton, A., Winner, E., Cronin, K., Overy, K. Dennis J.L., and Schlaug, G. (2005). Are there pre-existing neural, cognitive, or motoric markers for musical ability? Brain Cogn. *59*, 124–134.
Pietschnig, J., Voracek, M., and Formann, A.K. (2010). Mozart effect – Shmozart effect: A meta-analysis. Intelligence *38*, 314–323.
Piro, J.M. and Ortiz, C. (2009). The effect of piano lessons on the vocabulary and verbal sequencing skills of primary grade students. Psychol. Music *37*, 325–347.
Portowitz, A., Lichtenstein, O., Egorova, L., and Brand, E. (2009). Underlying mechanisms linking music education and cognitive modifiability. Research Studies in Music Education *31*, 107–128.
Postman, L. (1971). Transfer, interference and forgetting. In: J.W. Kling and L.A. Riggs, eds., Woodworth andSchlosberg's Experimental Psychology 3rd ed. New York: Holt, Rinehart and Winston, pp. 1019–1132.
Rauscher, F.H. and Shaw, G.L. (1998). Key components of the Mozart effect. Percept. Mot. Skills *86*, 835–841.
Rauscher, F.H., Shaw, G.L., and Ky, K.N. (1993). Music and spatial task performance. Nature *365*, 611.
Rauscher, F.H., Shaw, G.L., Levine, L.J., Wright, E.L., Dennis, W.R., and Newcomb, R. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning abilities. Neurol. Res. *19*, 2–8.
Register, D. (2001). The effects of an early intervention music curriculum on prereading/writing. J. Music Ther. *38*, 239–248.
Rickard, N.S., Bambrick, C.J., and Gill, A. (2012). Absence of widespread psychosocial and cognitive effects of school-based music instruction in 10-13 year old students. Int. J. Music Educ., published online/pre print publication, 3rd February 2012, 1–22.

Rose, F.C. ed. (2010). The Neurology of Music (London: Imperial College Press).
Scales, P.C., Benson, P.C., Roehlkepartain E.C., Sesma Jr., A., and van Dulmen, M. (2006). The role of developmental assets in predicting academic achievement: A longitudinal study. J. Adolesc. *29*, 691–708.
Schellenberg, E.G. (2004). Music lessons enhance IQ. Psychol. Sci. *15*, 511–514.
Schlaug, G., Jancke, L., Huang, Y., and Steinmetz, H. (1995). *In Vivo* evidence of structural brain asymmetry in musicians. Science *267*, 699–701.
Schlaug, G., Norton, A., Overy, K. and Winner, E. (2005). Effects of music training on the child's brain and cognitive development, Ann. N. Y. Acad. Sci. *1060*, 219–230.
Standley, J.M. (2008). Does music instruction help children learn to read? Evidence of a meta-analysis. Appl. Res. Music Educ. *27*, 17–32.
Strait D.L, Hornickel J., and Kraus N. (2011). Subcortical processing of speech regularities predicts reading and music aptitude in children. Behav. Brain Funct. *7*, 1–11.
Southgate, D.E. and Roscigno, V.J. (2009). The impact of music on childhood and adolescent achievement. Soc. Sci. Quart. *90*, 4–21.
Thorndike, E.L. (1906). Principles of teaching (New York: Seiler).
Thorndike, E.L. and Woodworth, R.S. (1901a). The influence of improvement in one mental function upon the efficiency of other functions: (I). Psychol. Rev. *8*, 247–261.
Thorndike, E.L. and Woodworth, R.S. (1901b). The influence of improvement in one mental function upon the efficiency of other functions: (II) The Estimation of magnitudes. Psychol. Rev. *8*, 384–395.
Thorndike, E.L. and Woodworth, R.S. (1901c). The influence of improvement in one mental function upon the efficiency of other functions: (III) Functions involving attention, observation and discrimination. Psychol. Rev. *8*, 553–564.
Tsang, C.D. and Conrad, N.J. (2011). Music training and reading readiness. Music Perception *29*, 157–163.
Vaughn, K. (2000). Music and mathematics: modest support for the oft-claimed relationship. J. Aesthetic Educ. *34*, 149–166.
Wells, G.A., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., and Tugwel, P. (2011). Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses, published online: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp

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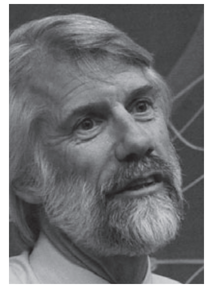

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