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RELATIONSHIPS BETWEEN EXTRACURRICULAR ACTIVITIES AND DEVELOPMENT OF COGNITIVE ABILITIES IN ESTONIAN PRIMARY SCHOOL CHILDREN

Master’s Thesis

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Relationships between extracurricular activities and development of cognitive abilities in Estonian primary school children

Abstract

Playing a musical instrument has been shown to be positively correlated with several cognitive abilities. In most of such research, authors have declared the need for conducting longitudinal research to better understand the mechanisms of the discovered correlations. The aim of this longitudinal natural experiment was to find out whether music training would accelerate the development of primary school children's working memory and intelligence relative to other types of extracurricular activities. The results showed that music training may indeed facilitate the development of children's general intelligence, but none of the hobby types studied here are related to the developmental speed of verbal or visual working memory. However, these results should be interpreted with caution due to several limits of the current data set which are discussed in detail. Future research should address this question with larger sample sizes and more elaborate materials and design.

Keywords: cognitive development, intelligence, working memory, extracurricular activities, hobbies, music training

Kooliväliste huvitegevuste mahtude ja kognitiivsete võimete arengu vahelised seosed Eesti algkoolilastel

Kokkuvõte

Pilliõpingutel on leitud positiivne seos erinevate kognitiivsete võimetega. Mitmed selliseid korrelatsioone leidnud teadlased on toonud välja vajaduse viia läbi longituud-uurimusi, mis võimaldaksid paremini mõista avastatud seoste mehhanisme. Siinse loodusliku eksperimendi eesmärk oli leida, kas pilliõpingud kiirendavad algkoolilaste töömälu ja intelligentsuse arengut võrreldes muud tüüpi huvitegevustega. Tulemused näitasid, et pilli õppimine võib tõepoolest aidata kaasa laste üldintelligentsuse arengule, kuid mitte ükski uuritud ei ole seotud verbaalse ja visuaalse töömälu arengu kiirusega. Tulenevalt mitmetest piirangutest, mida on siinses artiklis ka põhjalikult kirjeldatud, tuleks neid tulemusi intrepreteerida teatava ettevaatusega. Tulevastes töödes peaks olema eesmärgiks siinsele uurimisküsimusele vastamine suuremal valimil ja sobilikemate hindamisvahenditega.

Märksõnad: kognitiivsed võimed, intelligentsus, töömälu, huviharidus, hobid, pilliõpingud

"We are what we repeatedly do." – Aristotle

Our everyday life consists of a variety of frequently performed activities. Brain plasticity allows us to respond to the environmental demands placed by such activities by way of structural and functional changes in the central nervous system (Schlaug, 2001). For some complex abilities, such as learning a language, there has been found a critical period after which attaining proficiency is significantly more complicated (Hurford, 1991) than in a younger age when the brain appears to be more flexible in adapting to new tasks. Anatomical and physiological alterations in the brain often manifest in behavioural changes. For example, music training has been shown to induce structural adaptations in the brain which are correlated with the enhancement of musical skills (Hyde et al., 2009; Jäncke, 2009). Here I studied the relationship between different types of extracurricular activities and the development of school-aged children's cognitive abilities with a focus on the impact of music training.

Playing a musical instrument has been shown to be positively correlated with several cognitive abilities. Music training has been found to enhance reading skills (Hurwitz, Wolff, Bortnick, & Kokas, 1975; Anvari, Trainor, Woodside, & Levy, 2002), performance on spatial reasoning tasks (Rauscher, Shaw, Levine, Wright, Dennis, & Newcomb, 1997; Gromko & Poorman, 1998; Hetland, 2000b), verbal memory (Chan, Ho, & Cheung, 1998; Norton, Winner, Cronin, Overy, Lee, & Schlaug, 2005; Hogan & Huesman, 2008), and a few studies even report improvement of general intelligence (Schellenberg, 2004, 2011). However, cross-sectional studies do not allow us to make assumptions about the direction of the relationship between music training and cognitive abilities, as several of the previously cited authors have also noted. While it seems intuitive that learning to play an instrument might influence the development of broader cognitive abilities in a positive way, it is equally reasonable to hypothesize that children with greater cognitive skills would choose to engage and persist in music training. Furthermore, one interpretation does not exclude the other.

In most of the cross-sectional and correlational articles mentioned earlier, the authors have declared the need for conducting longitudinal research to better understand the mechanisms of the discovered correlations. Several such studies have already been published which longitudinally examine the relationship between music training and working memory in children (Ho, Cheung, & Chan, 2003; Norton, Winner, Cronin, Overy, Lee, & Schlaug, 2005;

Roden, Kreutz, & Bongard, 2012; Roden, Grube, Bongard, & Kreutz, 2014). Based on earlier findings of structural differences in musicians' brains (Schlaug, Jäncke, Huang, & Steinmetz, 1995), Ho et al. (2003) hypothesized that music training would probably benefit children's verbal but not visual working memory. Schlaug and colleagues (1995) found that the hemispheric asymmetry of the planum temporale was considerably higher in musicians compared to non-musicians as shown by magnetic resonance imaging. The planum temporale is a cortical area in the posterior part of the superior temporal gyrus. In the left hemisphere, the planum temporale forms a part of Wernicke's area and is involved in the verbal memory function (Schlaug et al., 1995). Consistent with their hypothesis, Ho et al.(2003) showed that a sample of Hong Kong boys benefited from music training, but the advantage was detectable only for verbal and not visual memory. The effects on verbal working memory have subsequently been corroborated (e.g. George & Coch, 2011; Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011; Roden, Kreutz, & Bongard, 2012), but research on visuo-spatial skills has yielded contradictory findings (Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003; Rauscher et al., 1997; Gromko & Poorman, 1998; Hetland, 2000b).

It is easy to understand why learning to play a musical instrument could affect some more general, not directly music-related skills. Working memory allows us to store and simultaneously manipulate sensory information for a relatively short period of time (Baddeley & Hitch, 1974). Playing an instrument requires one to rapidly process and integrate somatosensory, auditory, visual and motor information (Schlaug, 2009), tasks which heavily rely on working memory. No less important are other aspects of music making which involve a variety of cognitive abilities and psychological skills, such as creativity for interpreting a song or improvising, long-term memory for learning to play a piece of music by heart, social skills for playing together with other people and so on. As a hobby, music training takes up a large portion of time, as in addition to going to classes, the students are also required to practise independently. Independent practise time may vary greatly from individual to individual and is very difficult to control in a quasi-experimental study with children as participants. Nevertheless, active participation in music training cannot be overseen as a strong stimulus with a high probability of carry-over effects to non-music-specific abilities. This process is sometimes termed as transference and generally refers to a situation when experiences in one domain improve performance in another area (Hyde et al., 2009).

In the light of numerous findings of a multitude of faculties being positively correlated with or enhanced by music training, one could consider if there might exist a more general common variable that is responsible for the change observed in all the different cognitive skills. Schellenberg (2004, 2006, 2011) has proposed that general intelligence might play the described role and has published several interesting articles about the effects of music training on intelligence, including one where he was able to show the causal effect of playing an instrument on the heightening of intelligence (Schellenberg, 2004). If this is the case, then why are professional musicians not noticeably more intelligent than the general population? Schellenberg and Moreno (2010) have found that the differences in intelligence that can be seen in children are no longer significant when examining adults. The researchers suggest that music training can bring about notable benefits only if it is done in addition to and not instead of general studies (Schellenberg & Moreno, 2010). This interpretation should definitely be explored further.

An important question arising from these researchers' idea is that does an individual necessarily need to play an instrument to enhance his or her intelligence or is there some aspect about this activity, maybe also present in other hobbies, which influences the observed relationship. For example, playing sports has also been shown to improve children's cognitive abilities (Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008; Haapala, 2012). Could the effect be so robust that any kind of additional activity to the compulsory curriculum which requires regular utilization of cognitive skills also develops them significantly more when compared to individuals who do not take part in any such hobbies? Or is there also something specific about music training, maybe its high complexity, the underlying need to rapidly integrate sensory information form several modalities at a time and modify one's fine motor movements according to the multimodal feedback? One aspect which should be considered when discussing rather specific non-musical carry-over effects of music training is that learning to play an instrument often involves one-on-one coaching. Most other popular hobbies usually involve a much higher student-teacher ratio that could result in less individual attention to each participant. Thus, on the one hand, we should strive to conduct ecologically valid research where the participants choose their hobbies as they are in the real world, but on the other hand, we should complement such studies with experiments which allow us to exercise higher control over potential confounding variables.

In Estonia children traditionally start school at 7, but by that time most (e.g. 88% of 3- to 6-year-olds in 2014) have already attended preschool or kindergarten or some other type of classes where they can play and learn skills necessary for starting school (Statistics Estonia, 2017). These and other types of extracurricular activities, clubs and groups are of course non-compulsory, but they are quite popular. In 2014, out of the 73 072 children who were at the time five to nine years old, 44 766, that is approximately 60%, attended some type of hobby school (although some children might be counted twice in these data if they attended several institutions or types of activities) (Statistics Estonia, 2017). Of these 44 766, nearly 31.4% took part in music or arts clubs, 46.5% in sports, 1.6% in nature clubs, 1.2% in technology clubs, and 19.3% in general cultural activities. It is worth noting that in the areas of arts (including music) and sports in this age group there were stark gender differences. In the arts and music, 72.8% of the partakers were girls, but in sports their proportion was only 40.2%. In general, girls and boys were quite equally active in taking part in different hobbies (Statistics Estonia, 2017).

The design of the research reported here is a longitudinal quasi-experiment. The participants were not assigned to groups but instead chose their extracurricular activities independent of the study, as well as changed them whenever they desired. Even while being very flexible, informative and ecologically valid, such a design might suffer of low internal validity because many confounding variables were not controlled. In this thesis, time is considered as a within-subjects independent variable, i.e. the same participants were tested repeatedly over time. Between-subjects independent variable is the extracurricular activities of the participants and the time spent on each type of hobby. Dependent variables are the scores of verbal and visuo-spatial working memory tests, and Raven's Progressive Matrices, a measure of general intelligence. Possible uncontrolled confounding variables are socio-economic status, hobbies undertaken before the study and motivation.

The aim of this study was to find out whether music training would accelerate the development of children's working memory and intelligence when compared to other types of extracurricular activities. This study is novel because it is one of the few where the effects of music training are assessed longitudinally in a natural experiment, allowing to better understand changes taking place in time. To the best of our knowledge, it is also the first quasi-experimental study comparing actual hobbies taken up by children independent of taking part in this kind of a study. Based on the literature, we hypothesize that music training improves children's verbal working memory and general intelligence more than other types of hobbies.

Method

Participants

This study is the continuation of a seminar paper by Metshein (2015) where 132 children aged from 6 to 8 (M = 7.04, SD = 0.26) starting their first grade in a primary school were recruited on a voluntary basis from a total of five regular schools in Tartu and Tallinn, Estonia. The sample comprised of 63 girls and 69 boys whose parents had given a written informed consent prior to the start of the study. Each participant was tested in his or her school four times throughout the three-year study. During the first school year the children were tested twice, once during the autumn semester (baseline) and once in spring. At the beginning and at the end of first grade, information about the participants' extracurricular activities was collected from their parents. The aforementioned seminar paper included only these two assessment sessions which took place at the beginning and at the end of first grade. In the second and third grade, the participants were tested once a year. During the third and fourth test sessions, information about participants' hobbies (type and number of hours spent on each activity per week) was collected directly as self-reports. In this paper, extracurricular activity is defined as regular activity, supervised by a certified teacher or coach, which is not a part of the Estonian national curriculum, but chosen in addition to that by children and their parents. The dropout rate by the end of the study was 7.58%.

In the aforementioned seminar paper, the participants were divided into nominal groups based on criteria described by Metshein (2015). Here however, the amount of time that each child spent in each hobby category in hours per week was coded differently, creating six ratio level variables – one for each hobby category. The six categories of participants' hobbies used here are: MUSIC (learning to play a western musical instrument), SPORT (e.g., swimming, football; excluding all variations of sports which involve a lot of movement and music coordination, such as dancing), DANCE (sports involving body movement and music coordination, e.g., folk dance, ballet, gymnastics), BRAIN (activities such as robotics club, chess club, language lessons), SINGING (singing studio, choir, ensemble), and CREATIVE (drama club, visual arts, media club etc.). The categories formed on the basis of the types of extracurricular activities chosen by the participants. For each participant the number of hours per week spent on activities from each of these categories was recorded and for data analysis, the sum of hours spent on each type of activity during the three year span of the study was calculated.

The research project was approved by the Research Ethics Committee of the University of Tartu (permit no. 239/T-2).

Materials

Intelligence Intelligence was assessed with Raven's Standardized Progressive Matrices (Raven, 1976b). In this test, the person must use logic and reasoning in order to find the correct piece that is missing from a bigger puzzle. There are either six or eight pieces from which to choose. Raven's matrices were administered as a group test for up to 30 participants at a time. After the instructions were given, the children had 45 minutes to complete the test. Although the original Raven's matrices are not designed specifically for assessing children, the authors deem it appropriate for the goal of this study. Even 7-year-olds can solve the matrices as they are based on visual patterns and do not require advanced reading or writing abilities. As a result of Flynn effect (1987), the matrices originally intended to be used on adults can now successfully be used for assesing the general intelligence of children aged 7 to 10 without risking neither floor nor ceiling effect. Pullmann, Allik, and Lynn (2004) have also provided the norms for Estonian children for the test.

Working memory Working memory tests were administered to each participant individually. Visual working memory was assessed with a computerized spatial span test similar to that of the Corsi block-tapping task (Corsi, 1972; Cambridge Brain Sciences Inc, 2015). Before administering the visual working memory test, the participants were taught how to use the touchpad of a laptop. In the spatial span test the child had to observe the computer's screen on which there appeared a 4x4 matrice of gray squares. In random order, the squares then proceeded to turn yellow one by one for a duration of one second each. After a pattern of several squares had been displayed, the participant was expected to correctly reproduce the seen sequence by clicking on the squares using laptop's touchpad. The test started with a four-square series and if the child reproduced it correctly the next sequence would consist of five squares, but if they made an error, the number of squares in the next sequence would decrease by one square. After three inaccurate trials the test ended. Each participant completed the test twice and only their best result was taken into account.

Verbal working memory was assessed with a forward digit span task. The series of numbers, in a tempo of one word per second, were saved to a computer as a sound file and the researcher played the sequences to the participant through computer speakers. The first task was to verbally reproduce the heard digits in the same sequence as they were presented. The first series consisted of two numbers and if the child was able to reproduce them correctly, the next trial would be one number longer. Otherwise, the participant could hear the same sequence again for a second time. If they happened to make a mistake on a second try, they were allowed to hear a different succession with the same number of digits as the one they had failed to reproduce twice. That sequence could be heard for a second time as well before the test ended. The test came to an end if the participant was unable to correctly reproduce the second same-lenght sequence after hearing it for the second time (i.e., they could make up to four mistakes before testing was stopped). The number of digits in the longest series that the child could reproduce without error was considered to be the result of the digit span test. The second verbal working memory task, backward digit span, was carried out using the same procedure, but the participant was in this case asked to reproduce the sequences in a reverse order.

Data analysis

The data were analysed in R (R Development Core Team, 2017). The differences between the scores on the fourth and the first testing occasions, that took place approximately two and a half years apart, were found (henceforth referred to as change scores). The participants for whom this difference in Raven's matrices was at least minus two (n=5) were removed from the data as a decrease in change scores might be a sign of lack of motivation or hidden clinical problems. In all of the working memory tests a total of 18 participants had a change score of minus one which could still be considered spurious, thus, data from these 18 participants was included in the analyses.

Activity levels across different hobbies were correlated and could therefore not be modelled simultaneously in the framework of linear regression. Thus, using the raw data on levels of hobby activities, we were not able to account for the independent effects of each hobby activity (while controlling for time spent in other activities). Also, each hobby had to be modelled separately in order to avoid multicollinearity which led to the fitting of 24 multiple linear regression models: one for each combination of cognitive test type (four) and hobby category (six) with the amount of time spent on a type of hobby as a predictor, gender as a covariate, and change score on a test as a dependent variable. These results are reported in the Appendix. The number of independent regression models could not be reduced by combining the dependent variables into one factor as factor analysis showed that the cognitive test results were not describable by a single latent factor.

In order to overcome the constraints brought about by multicollinearity, we used principal component analysis with varimax (orthogonal) rotation. Firstly, as some of the hobby categories were intrinsically overlapping, we aggregated them: SPORT and DANCE formed the PHYSICAL category, and BRAIN and CREATIVE formed the MIND category. SINGING could not have been aggregated with MUSIC due to the aim of our study and we decided to leave the SINGING category out of further analyses. The structure of the loadings of the three hobby activities on the three rotated components was very clear (see Table 1). The principal components were able to account for practically all the variance in the data ($\chi^2 = 5 * 10^{-30}$; $RMS = 1 * 10^{-16}$). The scores of the rotated components were then used in the multiple regression models in place of the raw data reflecting the amount of time spent on the respective hobby activities. Significance level of .05 was used for all of the statistical tests.

A complicating issue in the analyses was also the fact that for almost half of the participants, some data were missing so the analyses would be based on a much smaller sample than expected. We tried imputation, but decided to disregard it especially given the rather explorative nature of this study, the small sample size, and the fact that imputations are shown to enhance noise and bring correlations closer to zero (Gelman & Hill, 2006).

Results

For testing our hypotheses, we first had to determine if there were any significant differences already at baseline. One-way ANOVAs where the gender and the school of the participant were controlled for, revealed that for all the hobby types the baseline score of Raven's matrices was on average 5.5 points higher ($p < .04$) for girls than for boys. There were no significant differences in the visuo-spatial working memory test nor the backward digit span at baseline. In the forward digit span however, at baseline, girls were again performing slightly better than boys achieving on average .36 higher points ($p < .05$). Such gender differences are to be expected as girls mature earlier than boys.

Spearman's rank correlation coefficients were calculated in order to find correlations between the amounts of time spent on different types of activities. Over the three years the amount of time spent on MUSIC was significantly and negatively correlated with time spent on SPORT, $\sigma = -.44$, $p < .001$. SPORT was also negatively correlated with DANCE, $\sigma = -.51$, $p < .001$, and positively with BRAIN, $\sigma = 0.29$, $p = .018$. Positive correlation was also found between SINGING and CREATIVE, $\sigma = 0.33$, $p = .007$.

The categories MUSIC, PHYSICAL and MIND formed three independent rotated components with the loadings of 1.0, .997 and .997 respectively (Table 1). We used linear regression models for assessing whether the amount of time spent on a hobby would predict the change scores of the different cognitive tests. Gender was included in all models, but not age, because it was recorded in whole years and thus did not have a proper variance [SD = 0.26; at the start of the study, most of the sample (123 children) consisted of 7-year-olds, with two 6-year-olds and seven 8-year-olds]. Unfortunately, none of the models came out to be statistically significant. However, the trends of the relationships between hobby categories and cognitive tests' change scores are still observable. We found that over the three years, time spent on MUSIC would enhance children's scores on Raven's progressive matrices by 1.62 points ($p = .06$) (see Table 2). None of the hobbies seemed to affect the change scores of the spatial span and the forward digit span tests (see Table 3 and Table 4). The backward digit span scores however show a trend of being slightly reduced by both MUSIC (.20 points, $p = .07$) and MIND (.21 points, $p = .06$) (see Table 5).

Table 1. Loadings of the three types of hobby categories on the rotated components (RC)

Rotated components	RC1	RC2	RC3
PHYSICAL	.997	.00	.00
MUSIC	.00	1.00	.00
MIND	.00	.00	.997

Table 2. Linear regression model for the change scores of Raven's Standard Progressive Matrices.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	11.70	1.10	10.67	.00
RC PHYSICAL	-.23	.79	-.29	.78
RC MUSIC	1.62	.85	1.91	.06
RC MIND	-.42	.80	-.52	.60
Gender (girl)	-2.08	1.66	-1.25	.22

Residual standard error: 6.04 on 54 df (2 observations deleted due to missingness)

Multiple R^2: .08, adjusted R^2: .01; $F(4, 54) = 1.15$, $p = .34$

Table 3. Linear regression model for the change scores of spatial span.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.03	0.16	6.53	.00
RC PHYSICAL	-.17	.12	-1.41	.17
RC MUSIC	.17	.12	1.38	.17
RC MIND	-.11	.12	-.88	.38
Gender (girl)	-.15	.24	-.62	.54

Residual standard error: .91 on 56 df

Multiple R^2: .08, adjusted R^2: .01; $F(4, 56) = 1.20$, $p = .32$

Table 4. Linear regression model for the change scores of forward digit span.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	.75	.13	5.70	.00
RC PHYSICAL	.10	.10	1.06	.30
RC MUSIC	.03	.10	.29	.77
RC MIND	-.07	.10	-.74	.46
Gender (girl)	-.30	.2	-1.48	.14

Residual standard error: .74 on 55 df (1 observation deleted due to missingness)

Multiple R^2: .06, adjusted R^2: -.01; $F(4, 55) = .83$, $p = .51$

Table 5. Linear regression model for the change scores of backward digit span.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.05	.15	7.24	.00
RC PHYSICAL	.00	.11	.02	.99
RC MUSIC	-.20	.11	-1.85	.07
RC MIND	-.21	.11	-1.90	.06
Gender (girl)	-.19	.22	-.83	.41

Residual standard error: .82 on 54 df (2 observations deleted due to missingness)

Multiple R^2: .13, adjusted R^2: .07; $F(4, 54) = 2.10$, $p = .09$

Discussion

In this paper I tried to find out if learning to play a musical instrument would accelerate the development of children's cognitive abilities when compared to other types of hobbies. Because of significant correlations between time spent on different types of extracurricular activities, I aggregated intrinsically overlapping hobby categories, and to test my hypotheses, carried out linear regressions with rotated components of the larger hobby groups. To corroborate the findings based on the rotated components, regressions with the raw data reflecting the amount of time spent on each type of hobby were run. The cognitive tests were all analysed separately as they did not fit well into any one latent factor model.
The large number of regressions would invariably lead to an increased type I error rate (as at 5% significance level, on average, 5% of tests of a similar kind would turn out significant even in the case when the null hypothesis holds in reality). It is difficult to assess the exact rate of this increase as not all the statistical tests run in this study are homogeneous (let alone that both raw data and rotated components were used in parallel), thus no correction for multiple comparisons was applied, but the reported statistical significances were interpreted cautiously throughout. This cautiousness is also warranted by the exploratory nature of the study, thus, in interpreting the results I focused rather on general trends.

The one expected result that was supported by both the rotated components' and raw data regressions was that music training can facilitate the development of children's general intelligence as reflected by the accelerated increase in the scores of Raven's progressive matrices. This result was evident both in the regression model of only MUSIC (Table 6 in Appendix) as well as the regression model with the levels of activities in MIND and PHYSICAL taken into account (in the latter case the result was trending towards significant; Table 2). This finding is in accordance with the work of Schellenberg (2004, 2006, 2011), who has extensively studied and found the positive effect of music training on intelligence. In case the result from rotated components' regression reflected "the true state of the world" that would be interpretable as the fact that there is added benefit of the nature of the hobby activity and it is not sufficient to just engage in any hobby in general (i.e. the accelerated increase in cognitive scores is not related to higher activity levels in general).

We did not find any one type of extracurricular activity to be more beneficial for visuo-spatial working memory than any other. Research on music training transference to visual working memory has yielded contradictory results with some authors finding positive (Rauscher et al., 1997; Gromko & Poorman, 1998; Hetland, 2000b) and others negative results (Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003). One of the reasons of this might be that there are several different ways for assessing visuo-spatial working memory, and some methods may be more focused on the capacity of the memory system while others put more emphasis on the spatial aspects.

An unforeseen result was the very slight negative trend of MUSIC and MIND on the backward digit span. This finding is in contradiction with my hypothesis and with previous results (e.g. George & Coch, 2011; Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011; Roden, Kreutz, & Bongard, 2012). These findings might be affected by the nature of the working memory tests used in this study. The capacity of the working memory tests to differentiate participants was weak and the dispersion of the scores quite low due to a possible ceiling effect. Future research should aim to use better and possibly multiple tests for assessing any one construct.

An interesting result (although invariably non-significant) was the lower speed of change in cognitive test scores in girls relative to boys. This trend occurred in absolutely all of the regression models with both rotated components and raw data alike, and in all the four cognitive tests. It is known that in primary school, girls tend to be slightly ahead of boys in cognitive development. This study might have focused on an age period when boys start to catch up and thus in comparison, girls' development seems to be slower.

One of the largest shortcomings of this study has been the considerable amount of missing data which could not have been successfully imputed. Out of 132 students, 127 were retained for the analyses and due to further missing data, only about half were included in the regressions. That also led us to leave the school factor out of the analyses as the cross-tables of change score values across different schools were highly sparse. A possible source of the problem might be the different way information about participants' extracurricular activities was collected at the beginning and later in the study. As the parent-reported information was focused on music training and sport, some data from the first year of the study may not reflect the full variety of hobbies undertaken by the participants. The quality of the data relative to the aims of this study was much higher on the third and fourth assessment sessions. In addition to the already reduced sample size, some participants obtained negative change scores and thus had to be left out of the analyses. There is reason to assume that some of them had unreported clinical problems that might have affected their performance.

The shortcomings of this study could be taken into account when conducting similar research in the future. The biggest problem seems to be the small sample size but to considerably enlarge it would require the work of a whole research group rather than one graduate student. Another important aspect to improve is the choice of tests for assessing cognitive development in children, preferring such that can form a single factor. While Raven’s Standard Progressive Matrices seemed good for assessing the development of general intelligence in this age group, the working memory tests appeared to have a too low capacity for differentiating the participants, possibly due to ceiling effect. Nevertheless, this study has been successful in corroborating previous findings which show that music training has the potential to enhance children’s cognitive development. It has also proven that studying such relationships in an ecologically valid natural experiment requires a very thought through design and a large sample of participants.

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Appendix

Table 6
Linear regression model for the change scores of Raven's Standard Progressive Matrices (RSPM) and MUSIC.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	10.48	1.12	9.39	.00
sumMUSIC	.83	.40	2.09	.04
Gender (girl)	-2.27	1.58	-1.43	.16

Residual standard error: 5.936 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .085, adjusted R^2: .053; $F(2,57) = 2.644$, $p = .08$

Table 7
Linear regression model for the change scores of RSPM and SPORT.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	12.76	1.86	6.85	.00
sumSPORT	-.17	.17	-.98	.33
Gender (girl)	-2.17	1.74	-1.25	.22

Residual standard error: 6.109 on 57 df (67 observations deleted due to missingness)
Multiple R^2: 0.031, adjusted R^2: -.003; $F(2, 57) = .903$, $p = .411$

Table 8
Linear regression model for the change scores of RSPM and DANCE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	11.27	1.09	10.35	.00
sumDANCE	.05	.13	.39	.70
Gender (girl)	-1.75	1.76	-1.00	.32

Residual standard error: 6.151 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .017, adjusted R^2: -.017; $F(2, 57) = .497$, $p = .611$

Table 9
Linear regression model for the change scores of RSPM and BRAIN.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	11.70	1.28	9.11	.00
sumBRAIN	-.31	.51	-.61	.55
Gender (girl)	-1.51	1.68	-.90	.37

Residual standard error: 6.124 on 56 df (68 observations deleted due to missingness)
Multiple R^2: .016, adjusted R^2: -.019; $F(2, 56) = .469$, $p = .628$

Table 10
Linear regression model for the change scores of RSPM and CREATIVE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	11.28	1.13	9.94	.00
sumCREATIVE	.01	.52	.01	.99
Gender (girl)	-1.21	1.62	-.75	.46

Residual standard error: 6.145 on 56 df (68 observations deleted due to missingness)
Multiple R^2: .01, adjusted R^2: -.025; $F(2, 56) = .283$, $p = .755$

Table 11
Linear regression model for the change scores of RSPM and SINGING.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	11.10	1.11	9.98	.00
sumSINGING	.27	.40	.69	.50
Gender (girl)	-1.43	1.63	-.88	.38

Residual standard error: 6.119 on 56 DF (68 observations deleted due to missingness)
Multiple R^2: .018, adjusted R^2: -.017; $F(2, 56) = .521$, $p = .597$

Table 12
Linear regression model for the change scores of spatial span and MUSIC.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	.91	.17	5.47	.00
sumMUSIC	.08	.06	1.39	.17
Gender (girl)	-.14	.24	-.59	.56

Residual standard error: 0.905 on 59 df (65 observations deleted due to missingness)
Multiple R^2: .03326, adjusted R^2: .0; $F(2, 59) = 1.015$, $p = .369$

Table 13
Linear regression model for the change scores of spatial span and SPORT.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.29	.28	4.67	.00
sumSPORT	-.03	.03	-1.27	.21
Gender (girl)	-.21	.26	-.83	.41

Residual standard error: 0.907 on 59 df (65 observations deleted due to missingness)
Multiple R^2: .02817, adjusted R^2: -.005; $F(2, 59) = .855$, $p = .43$

Table 14
Linear regression model for the change scores of spatial span and DANCE.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.00	.16	6.38	.00
sumDANCE	-.01	.02	-.52	.60
Gender (girl)	-.02	.26	-.06	.95

Residual standard error: 0.917 on 59 df (65 observations deleted due to missingness)
Multiple R^2: .006, adjusted R^2: -.028; $F(2, 59) = .183$, $p = .833$

Table 15
Linear regression model for the change scores of spatial span and BRAIN.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.10	.19	5.81	.00
sumBRAIN	-.07	.08	-.97	.34
Gender (girl)	-.15	.25	-.60	.55

Residual standard error: 0.92 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .018, adjusted R^2: -.016; $F(2, 58) = .521$, $p = .597$

Table 16
Linear regression model for the change scores of spatial span and CREATIVE.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	1.0	.17	5.97	.00
sumCREATIVE	.00	.08	.01	1.0
Gender (girl)	-.07	.24	-.31	.76

Residual standard error: 0.927 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .002, adjusted R^2: -.033; $F(2, 58) = .048$, $p = .953$

Table 17
Linear regression model for the change scores of spatial span and SINGING.

	β	SE	*t* value	*p* (>|*t*|)
(Intercept)	.99	.17	5.96	.00
sumSINGING	.02	.06	.30	.76
Gender (girl)	-.09	.24	-.36	.72

Residual standard error: 0.926 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .003, adjusted R^2: -.031; $F(2, 58) = .094$, $p = .91$

Table 18
Linear regression model for the change scores of forward digit span and MUSIC.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.72	.14	5.19	.00
sumMUSIC	.01	.05	.15	.88
Gender (girl)	-.23	.19	-1.21	.23

Residual standard error: 0.737 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .025, adjusted R^2: -.009; $F(2, 58) = .731$, $p = .486$

Table 19
Linear regression model for the change scores of forward digit span and SPORT.

	Β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.88	.22	3.92	.00
sumSPORT	-.02	.02	-.83	.41
Gender (girl)	-.30	.21	-1.45	.15

Residual standard error: 0.733 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .036, adjusted R^2: .002; $F(2, 58) = 1.07$, $p = .35$

Table 20
Linear regression model for the change scores of forward digit span and DANCE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.72	.13	5.73	.00
sumDANCE	.03	.02	1.80	.08
Gender (girl)	-.38	.20	-1.87	.07

Residual standard error: 0.718 on 58 df (66 observations deleted due to missingness)
Multiple R^2: .076, adjusted R^2: .044; $F(2, 58) = 2.376$, $p = .102$

Table 21
Linear regression model for the change scores of forward digit span and BRAIN.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.82	.15	5.37	.00
sumBRAIN	-.07	.06	-1.07	.29
Gender (girl)	-.31	.20	-1.55	.13

Residual standard error: 0.734 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .047, adjusted R^2: .013; $F(2, 57) = 1.401$, $p = .255$

Table 22
Linear regression model for the change scores of forward digit span and CREATIVE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.73	.14	5.34	.00
sumCREATIVE	.00	.06	.03	.97
Gender (girl)	-.25	.19	-1.27	.21

Residual standard error: 0.741 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .028, adjusted R^2: -.006; $F(2, 57) = .818$, $p = .447$

Table 23
Linear regression model for the change scores of forward digit span and SINGING.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.74	.13	5.53	.00
sumSINGING	-.01	.05	-.26	.80
Gender (girl)	-.24	.20	-1.21	.23

Residual standard error: 0.74 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .029, adjusted R^2: -.005; $F(2, 57) = .852$, $p = .432$

Table 24
Linear regression model for the change scores of backward digit span and MUSIC.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	1.16	.16	7.41	.00
sumMUSIC	-.09	.05	-1.74	.09
Gender (girl)	-.17	.22	-.78	.44

Residual standard error: 0.836 on df (67 observations deleted due to missingness)
Multiple R^2: .071, adjusted R^2: .038; $F(2, 57) = 2.163$, $p = .124$

Table 25
Linear regression model for the change scores of backward digit span and SPORT.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	.71	.26	2.76	.01
sumSPORT	.04	.02	1.67	.10
Gender (girl)	-.08	.24	-.31	.76

Residual standard error: 0.838 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .067, adjusted R^2: .034; $F(2, 57) = 2.031$, $p = .141$

Table 26
Linear regression model for the change scores of backward digit span and DANCE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	1.07	.15	7.20	.00
sumDANCE	-.02	.02	-1.00	.32
Gender (girl)	-.14	.24	-.59	.56

Residual standard error: 0.851 on 57 df (67 observations deleted due to missingness)
Multiple R^2: .038, adjusted R^2: .004; $F(2, 57) = 1.118$, $p = .334$

Table 27
Linear regression model for the change scores of backward digit span and BRAIN.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	1.24	.17	7.21	.00
sumBRAIN	-.14	.07	-1.93	.06
Gender (girl)	-.34	.23	-1.5	.14

Residual standard error: 0.831 on 56 df (68 observations deleted due to missingness)
Multiple R^2: .077, adjusted R^2: .044; $F(2, 56) = 2.349$, $p = .105$

Table 28
Linear regression model for the change scores of backward digit span and CREATIVE.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	1.09	.16	6.92	.00
sumCREATIVE	-.04	.07	-.55	.59
Gender (girl)	-.20	.23	-.88	.38

Residual standard error: 0.856 on 56 df (68 observations deleted due to missingness)
Multiple R^2: .021, adjusted R^2: -.014; $F(2, 56) = .605$, $p = .55$

Table 29
Linear regression model for the change scores of backward digit span and SINGING.

	β	**SE**	***t* value**	***p* (>|*t*|)**
(Intercept)	1.08	.15	7.03	.00
sumSINGING	-.03	.06	-.57	.57
Gender (girl)	-.19	.23	-.83	.41

Residual standard error: 0.856 on 56 df (68 observations deleted due to missingness)
Multiple R^2: .022, adjusted R^2: -.013; $F(2, 56) = .617$, $p = .543$

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