

## Music Training, Cognitive Abilities and Self-Concept of Ability in Children

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### ABSTRACT

It is assumed that music training influences non-musical abilities positively. We tested the influence of an extended music curriculum (EMC) at school, consisting of musical instrument, auditory perception and music theory training, on children's specific cognitive abilities and their self-concept of ability. We compared 45 10-year-old children just started EMC (Study 1) and 31 13-year-old children attending EMC for 2 years (Study 2) to children not attending EMC. In Study 3 after one year 34 children of Study 1 were retested. Confounding variables, like intelligence, socioeconomic status (SES) and extracurricular schooling were controlled. In all studies children with and without EMC did not differ significantly in intelligence, SES and extracurricular schooling.

In Study 1 (3 months EMC) children with EMC showed significantly higher musical, spatial and language abilities. In Study 2 (33 months EMC) children with EMC showed significantly higher abilities than children without EMC in the same abilities as in Study 1 (music, language). Moreover, children with EMC outperformed their peers without EMC in attention and memory and reported higher self-concepts of ability. In Study 3 (15 months EMC) children with EMC showed significantly higher language abilities, attention scores and first tendencies as well as significant differences in self-concept of ability.

We conclude that music training (EMC) influences children's cognitive abilities and the attitude towards their abilities (self-concept of ability) positively.

### I. INTRODUCTION

The idea of non-musical benefits of music training has received considerable attention from the public and the media, and it has been controversially discussed by the scientific community. Scientific studies have addressed the issue of non-musical benefits with different approaches. In one line of research, the relationship between music training and / or musical ability and *intelligence* has been investigated. For example, Gruhn, Galley and Kluth (2003) found a positive relation between mental speed and musical ability in 3- to 7-year-old children. Schellenberg (2003) tested 6- and 11-year-old children, using a correlational approach to examine whether music lessons are predictive of intellectual development, measured by full-scale IQ. Months of music lessons had the strongest association with IQ, stronger than socioeconomic status, parental education and time spent in non-musical extracurricular activities. In order to directly test the hypothesis that, "music makes you smarter", Schellenberg (2004) carried out an experiment. He assigned 6-year-old children randomly to keyboard lessons, voice lessons, drama

lessons and no lessons and found that children, receiving music lessons, show greater full-scale IQ increases than children assigned to drama or no lessons. Thus, the causal direction should go from music lessons to IQ. Since the increase was evident across all IQ subtests, the conclusion was that music lessons influence general intelligence. Although the effects of music lessons were relatively small, they were long lasting (Schellenberg, 2006).

In another line of research, the relationship between music training and / or musical ability and *specific cognitive abilities* has been investigated. In contrast to the small effects on general intelligence, relations between music training and / or musical ability and specific cognitive abilities seem to be more pronounced. Numerous studies focus on the relation between musical and language ability. Anvari, Trainor, Woodside and Levy (2002) revealed, in a correlational study with 4- and 5-year-old children, significant positive relations between musical ability and both phonological awareness and reading skills. Ho, Cheung and Chan (2003) found that musically trained 6- to 15- year-old children outperform their untrained counterparts in verbal but not visual memory. The relationship between music lessons and verbal memory is also evident in adults: Jakobson, Cuddy and Kilgour (2003) revealed a positive association between years of formal music training and verbal recall in undergraduates.

Another specific cognitive ability, which has been intensely studied in relation to music training or ability, is spatial reasoning. Some studies show relations between musical expertise and spatial reasoning. Brochard, Dufour and Després (2004) revealed significantly shorter reaction times for musicians compared to nonmusicians, in a visual perception and imagery task. In a study by Neuhoff, Knight and Wayand (2002) listeners with more musical experience were significantly better in mapping and scaling the amount of pitch change that they heard in non-standard musical intervals in comparison to novice listeners. The advantage from musicians over nonmusicians in visual spatial tasks was also found in children. Rauscher et al. (1997) reported in a study with preschoolers a significant enhancement of spatial-temporal reasoning in children, receiving keyboard lessons, compared to children, receiving computer lessons or no lessons. Also Bilhartz, Bruhn and Olson (2000) found evidence for a correspondence between early music instruction and spatial-temporal reasoning abilities. In a meta-analysis Hetland (2000) concludes that music training enhances spatial-temporal performance in preschool and elementary school children. She

asserts that the effect is moderate, but amazingly consistent across the populations, included in the meta-analysis.

Other cognitive abilities like mathematical ability, attention or motor abilities and their relation to music training and / or musical ability have been subject of investigation as well; see Schumacher (2006) for an overview. There is evidence of positive associations between music training and / or music ability and attention. Scott (1992) revealed that in 3- and 5-year-old children a musically trained group scored higher in attention than a creative movement or a preschool group. Costa-Giomi (2005) found that children who participated in two years of piano instruction significantly improved their fine motor abilities. Additionally in comparison to children who never had formal music training, the children participating in piano instruction were faster in a speed response task.

Taken together an effect of music training and / or music ability is evident for more global cognitive abilities like intelligence as well as for specific cognitive abilities such as language abilities and spatial reasoning. These effects seem to be small or moderate, but long lasting. The causal relation between music training and / or music ability and cognitive abilities remains, due to mostly correlational approaches, more or less unclear.

Several explanations for the relation between music training and / or musical ability and general or specific cognitive abilities have been discussed. Possible explanations, for example, are: neuronal changes due to music training, the possibility that high IQ children could be more motivated to take music lessons or schooling effects, for more explanations see Schellenberg (2006). Regarding this issue other interesting findings like increased school motivation due to musical training (Zehr, 2003), higher perseverance in musically trained than in untrained children (Scott, 1992) and higher self-esteem in children with piano instruction compared to children without piano instruction (Costa-Giomi, 2004) should also be taken into consideration as possible explanations for the positive effects of music training on cognitive abilities. Music training could affect motivational factors of participating children as a consequence of self-efficacy experiences. Therefore variables like the self-concept of ability, a motivational factor that is associated with a person's achievement (Valentine, DuBois & Cooper, 2004), could shed light on the search of possible explanations. In the way that music training provides an additional input of positive experiences and therefore could increase self-concept of ability. Hence, high self-concepts of ability are associated with higher task persistence and less task irrelevant thoughts (Schöne, Dickhäuser, Spinath & Stiensmeier-Pelster, 2002) which result in more attention for the actual task. Thus these associations between self-concept of ability and task performance enable children, with high self-concepts of ability, to perform well in achievement situations and cognitive tasks.

Previous studies investigated mainly the relation between general (intelligence) or specific (language or spatial-temporal abilities) cognitive abilities and music training or musical ability. The relation between specific musical abilities (music perception or production) and specific cognitive abilities needs further investigation. It is essential in further studies to control for confounding variables, like intelligence, socioeconomic status and extracurricular schooling in order to exclude

alternative explanations. It is important to note that nearly all reported findings on associations between music training and cognitive abilities are based on correlation studies testing children of different ages in a cross sectional manner. However, to what extent music training really causes changes in cognitive abilities cannot be answered by such methodological approaches. A causal relationship between music training and cognitive reactions can only be drawn from longitudinal studies. So far, there are only few studies using a longitudinal approach. For example, Fujioka et al. (2006) tested 4 to 6 year-old children's auditory evoked responses to a violin tone and a noise-burst stimulus in 4 repeated measurements over a 1 year period using magnetoencephalography (MEG); half of the children participated in music lessons throughout the year, the other half had no music lessons. Among other results, a clear music training effect was expressed in a larger and earlier N250m peak in the left hemisphere in response to the sound of a violin in musically trained children compared with musically untrained children. Schlaug et al. (2005) started a longitudinal study with 5 to 7 year-old children to investigate whether music instrument training led to cognitive enhancement and would stimulate regional growth in brain areas shown to be structurally different in adult musicians. They tested one group of children prior to music lessons and compared these with a control group matched in age, socioeconomic standard, and verbal IQ. All children underwent a battery of behavioural tests including some subtests of the WISC-III, the Raven's matrices test, a test of phonemic awareness, a music test (PMMA), and a motor test. Children also underwent structural and functional MRI scans. After one year, the first results showed greater changes in scores for the music and motor tests in the group that had completed instrument training compared with the control group. No evidence was found for transfer effects in domains such as verbal, visuo-spatial, or mathematical abilities. Only trends could be observed in the anticipated direction as was the case for the brain data. Moreno et al. (2009) conducted a longitudinal study with 8-year-olds. Children were assigned pseudo randomly to music or painting training. In the music training group children showed an increase in reading ability and pitch discrimination abilities in speech.

Taken together there is evidence for neuronal changes due to music training. Regarding language abilities longitudinal studies indicate a positive relation to music training. By now it is important to enlarge the observation period and include a variety of cognitive variables of interest.

The aim of this study was to examine the relation between music training and / or musical ability and specific cognitive abilities as well as the relation between specific musical abilities (music perception and production) and cognitive abilities in a cross sectional and longitudinal manner. Therefore children with different amounts of music training compared to musically untrained children were tested and confounding variable like intelligence, socioeconomic status and extracurricular schooling were controlled. Additionally the self-concept of ability was measured to investigate a possible mediator of the positive effect of music training on cognitive abilities.

In Study 1 children, who had just started music training, were compared to their untrained counterparts in musical and cognitive abilities and self-concept of ability. In Study 2

children, participating for more than two years in music training, were compared to untrained children in musical and cognitive abilities and self-concept of ability. In Study 3 the children from Study 1 were tested a year after the first testing session in musical and cognitive abilities and self-concept of ability.

## II. Study 1

### A. Method

1) *Participants.* The sample comprised 45 (25 girls) 9-to11-year-olds ( $Md = 10$  years; 9 months) recruited from a secondary school in Giessen, Germany. 20 (13 girls) of the children participated in an extended music curriculum (EMC) at school, consisting of private instruction on at least one musical instrument, two additional music lessons per week (all other pupils have only one music lesson per week), one music lesson in which the pupils of a music class are playing together on their instruments and at least two or up to four hours per week of practical musical training in the school choir and/or in the school orchestra. By the time of testing children attended EMC for about  $Md = 3$  months. Far more girls participate in the extended music curriculum, thus our sample comprises more girls than boys in the EMC group. In the group not attending EMC ( $n = 25$ ) a nearly equal amount of boys (11) and girls (14) participated in the study.

2) *Measures.* Specific cognitive abilities, like spatial reasoning, phonological awareness, visual and auditory attention, sensorimotor-functions, verbal-, visual- and auditory memory, were measured as well as music abilities (production and perception) and self-concept of ability. We controlled for possible confounding variables such as intelligence, socioeconomic status and extracurricular schooling.

*Control variables:* Intelligence was measured using the “mosaic test”, the “vocabulary test”, the “general knowledge test”, and the “arranging pictures in a logical sequence test” of the HAWIK III (Hamburg-Wechsler-Intelligenztest für Kinder; Tewes, Rossmann and Schallberger, 2000). Socioeconomic status, measured by parents’ education, and extracurricular schooling were assessed with a questionnaire designed by the authors.

*Musical abilities:* Music production abilities were tested with the music screening for children by Jungbluth and Hafen (2005). Children were asked to memorize and to sing a song, to replay a given rhythm and to execute a metre. Music production abilities were scored independently by two raters and their interrater reliability for music production was  $r = .962$ . Music perception abilities were assessed using the Advanced Measure of Music Audiation (Gordon, 1989). Children had to decide on the sameness or difference of two consecutive musical pieces. In case of a perceived difference, the decision had to be made whether this difference is tonal or rhythmical.

*Specific cognitive abilities:* Spatial reasoning was tested using the mosaic test of the HAWIK III (Tewes, Rossmann & Schallberger, 2000), phonological awareness was measured with three subtests from the BAKO (Basiskompetenzen für Lese- und Rechtschreibleistungen; Stock, Marx & Schneider, 2003). Attention was tested using the auditory attention and

response set from a neuropsychological test battery (NEPSY; Korkman, Kirk & Kemp, 1998), and a more visual aligned form of attention was measured by the attention and stress measurement “d2” (Brickenkamp, 2002). Sensorimotor-functions were assessed with the subtests “eye-hand coordination” and “visual-motor-speed” of the DTVP (Developmental Test of Visual Perception; Hammill, Pearson & Voress, 1993). Three different scores for memory were measured: First verbal memory measured with a list learning procedure (Helmstaedter, Lendt & Lux, 2001). The verbal memory test provided a total test score for verbal memory, an immediate recall score (words correctly remembered from the target list after the first turn), a learning efficiency score (the amount of words learned from a target list from immediate recall until the last recall opportunity from the target list), an interference score (loss of words from the target list after learning a non target list) and a delayed verbal memory score (words correctly remembered from the target list after a 20 minutes interval). Second visual memory measured with colour sequences and third auditory memory measured with sound sequences both subtests of the BASIC-MLT (Battery for Assessment in Children – Merk- und Lernfähigkeitstest für 6- bis 16-Jährige; Lepach & Petermann, 2008).

The *self-concept of ability* was assessed with a questionnaire (Skalen zur Erfassung des Schulischen Selbstkonzeptes; Schöne, Dickhäuser, Spinath & Stiensmeier-Pelster, 2002) measuring criterial, individual, social and absolute self-concept of ability. The four scores differ with respect to their benchmarks, for criterial the benchmark is an objective measure, for individual the benchmark is the own former achievement, for social the benchmark is the social comparison and for absolute self-concept of ability no benchmark can be identified.

### B. Results and Discussion

Assumptions for parametric testing were verified. In case of violation of these assumptions appropriate nonparametric tests were used.

1) *Sample characteristics.* To make sure that the group of children, attending and not attending extended music curriculum do not differ in possible confounding variables, the control variables (intelligence, socioeconomic status and extracurricular schooling) were assessed.

There were no significant differences between the groups in their intelligence scores ( $t(42) = -0.54; p = .592$ ) and the socioeconomic status (mother  $\chi^2(1, N = 37) = 0.217, p = .642$ ; father  $\chi^2(1, N = 35) = 1.786, p = .181$ ). For extracurricular schooling no significant difference, but a tendency for more extracurricular schooling in children attending the EMC, was revealed ( $t(42) = -1.94; p = .063$ ).

2) *Musical and specific cognitive abilities.* Statistics for the group comparisons are provided in Table 1. After participation for about three months in the EMC, children attending EMC scored significantly higher ( $M = 8.13; SD = 2.86; t(42) = -2.526, p = .015, r = .363$ ) in metre execution, one component of music production abilities, as children not attending EMC ( $M = 5.98; SD = 2.76$ ). As for the other measures of music

production and perception no significant differences between children attending and not attending EMC was found.

Concerning the specific cognitive abilities significant differences between children attending and not attending EMC were found for spatial and language abilities in favour of the children attending extended music curriculum.

Children attending EMC ( $M = 12.16$ ;  $SD = 2.17$ ) scored significantly higher in spatial reasoning ( $U = 151$ ,  $p = .038$ ,  $r = .276$ ) as children not attending EMC ( $M = 10.68$ ;  $SD = 2.12$ ). With respect to language abilities phonological awareness and verbal memory was assessed. Children attending EMC showed a tendency to score higher on phonological awareness ( $t(43) = -1.88$ ,  $p = .067$ ,  $r = .276$ ). Additionally in verbal memory the children attending EMC ( $M = 7.30$ ;  $SD = 1.98$ ) outperformed their non attending counterparts ( $M = 5.28$ ;  $SD = 1.93$ ) in learning efficiency for verbal material ( $U = 118$ ,  $p = .002$ ,  $r = .454$ ). Surprisingly in immediate recall of verbal material, the children not attending EMC scored significantly higher than children attending EMC ( $U = 155$ ,  $p = .028$ ,  $r = .454$ ), see Table 1 for descriptive statistics.

**Table 1. Mean and standard deviation for control variables, music and cognitive abilities and self-concept of ability in children attending and not attending EMC.**

	9- to 11-year-olds			
	EMC		no EMC	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
IQ	108.63	14.13	106.42	12.91
extracurricular schooling	119	83.7	76.38	53.89
music production *	8.13	2.86	5.98	2.76
music perception	47.05	4.95	45.64	9.45
spatial reasoning *	12.16	2.17	10.68	2.12
phonological awareness #	18.15	5.49	14.60	6.88
verbal memory learning efficiency **	7.30	1.98	5.28	1.93
verbal memory immediate recall *	6.30	1.30	7.44	1.76
critical self-concept of ability	59.1	7.76	56.08	8.65
individual self-concept of ability	52.75	13.09	50.4	9.46
social self-concept of ability	55.2	7.19	52.28	8.45
absolute self-concept of ability	55.85	9.12	55.32	9.67

*Note.* EMC = attending extended music curriculum. no EMC = not attending extended music curriculum. \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed.

3) *Correlations between musical and cognitive abilities.* Music production abilities were significantly related to phonological awareness ( $r = .371$ ;  $p = .014$ ). Memorizing and singing a song, a specific element of music production, was associated with phonological awareness ( $r = .314$ ;  $p = .038$ ), whereas metre execution, also an element of music production, was related to phonological awareness ( $r = .308$ ;  $p = .042$ ),

verbal memory ( $r = .362$ ;  $p = .016$ ) and eye hand coordination ( $r = .291$ ;  $p = .056$ ), one of the measures for sensorimotor-functions.

Music perception abilities were significantly correlated to lexicon ( $r = .379$ ;  $p = .011$ ) and auditory memory ( $r = .323$ ;  $p = .030$ ). Surprisingly a significant correlation between errors in auditory attention and music perception was found ( $r = .308$ ;  $p = .040$ ). The tonal score of music perception was associated with errors in auditory attention ( $r = .412$ ;  $p = .005$ ). High scores in tonal perception were followed by a high amount of errors in auditory attention. The perception ability for rhythm was related to lexicon ( $r = .316$ ;  $p = .037$ ).

4) *Self-concept of ability.* In all four scores of self-concept of ability (critical, individual, social, absolute) no significant differences between children attending and not attending EMC were found, see Table 2 for statistics.

Taken together, we found, after the first three months of attending the extended music curriculum, in comparable groups, with respect to intelligence, socioeconomic status and extracurricular schooling, significant differences, in favour of the musically trained group, in music production ability, spatial and language ability. Only for immediate recall the children not attending EMC outperformed their attending counterparts. Furthermore, music production was correlated to phonological awareness and verbal memory (language ability) and sensorimotor-functions and music perception ability was related to lexicon (language ability) and auditory memory. A relation between music perception and errors in auditory attention was found. Regarding the self-concept of ability, no significant difference between children attending and not attending EMC was found. The results suggest that, after a short period of music training, first effects on musical and cognitive abilities are present. Nevertheless some results were surprising, because in domains like immediate recall and errors in auditory attention one would intuitively expect an advantage of the musically trained group over the untrained. To see whether the expected and unexpected results change with longer periods of music training a group of children, musically trained for 33 months were tested in Study 2.

### III. Study 2

#### A. Method

1) *Participants.* The participants were 31 (16 girls) children from secondary schools in Giessen, Germany. The children ranged in age from 11 to 14 years ( $Md = 13$  years; 2 months). 18 (11 girls) of the children participated in an extended music curriculum (EMC) at school. By the time of testing children attended EMC for about  $Md = 33$  months. Far more girls participate in the extended music curriculum, thus our sample also comprises more girls than boys in the EMC group. From the group not attending EMC ( $n = 13$ ) 8 boys and 5 girls participated in the study.

2) *Measures.* We employed the same measures for the specific cognitive abilities, the musical abilities, the self-concept of ability and the control variables as in Study 1. Two independent rater rated the music production score and their interrater reliability was  $r = .995$ .

## B. Results and Discussion

Assumptions for parametric testing were verified. In case of violation of these assumptions appropriate nonparametric tests were used.

1) *Sample characteristics.* To make sure that the group of children, attending and not attending extended music curriculum do not differ in possible confounding variables, the control variables (intelligence, socioeconomic status and extracurricular schooling) were assessed. There were no significant differences between the groups in their intelligence scores ( $t(29) = -0.693$ ;  $p = .494$ ), the socioeconomic status (mother  $\chi^2(1, N = 31) = 0.111$ ,  $p = .739$ ; father  $\chi^2(1, N = 31) = 2.162$ ,  $p = .141$ ) and extracurricular schooling ( $t(29) = -0.994$ ;  $p = .329$ ).

2) *Musical and specific cognitive abilities.* Statistics for the group comparisons are provided in Table 2. After participation for about 33 months in the EMC, children attending EMC ( $M = 8.64$ ;  $SD = 2.56$ ) scored significantly ( $t(29) = -2.526$ ,  $p = .017$ ,  $r = .425$ ) higher in metre execution as children not attending EMC ( $M = 6.12$ ;  $SD = 2.99$ ). Regarding the other measures of music production and perception no significant differences between children attending and not attending EMC was found.

**Table 2. Mean and standard deviation for control variables, music and cognitive abilities and self-concept of ability in children attending and not attending EMC.**

	11- to 14-year-olds			
	EMC		no EMC	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
IQ	105.56	19.12	101.26	13.57
extracurricular schooling	141.1	73.28	115.54	66.91
music production *	8.64	2.56	6.12	2.99
music perception	47.72	8.59	47.31	7.04
verbal memory immediate recall**	8.94	1.86	7.00	1.23
verbal memory learning efficiency**	4.61	1.81	6.62	1.39
verbal memory loss due to interference *	1.11	1.37	2.31	1.60
visual attention *	414.72	47.36	372.67	46.65
visual memory #	9.22	2.05	8.00	1.08
critical self-concept of ability*	59.44	10.76	51.08	7.39
absolute self-concept of ability*	54.33	8.70	47.92	7.91

*Note.* EMC = attending extended music curriculum. no EMC = not attending extended music curriculum. # $p < .1$ , two-tailed. \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed.

In terms of the specific cognitive abilities differences between children attending and not attending EMC were found for language abilities, attention and visual memory in favour of the children attending extended music curriculum.

In language abilities children attending EMC scored significantly higher in immediate recall for verbal material ( $U = 49.5$ ;  $p = .006$ ,  $r = .494$ ). Additionally in verbal memory the

children attending EMC ( $M = 1.11$ ;  $SD = 1.37$ ) scored lower as the children without EMC ( $M = 2.31$ ;  $SD = 1.6$ ) in amount of words lost due to interference ( $U = 64.5$ ,  $p = .031$ ,  $r = .388$ ). Surprisingly in learning efficiency for verbal material, the children not attending EMC scored significantly higher than children attending EMC ( $U = 46$ ,  $p = .004$ ,  $r = .517$ ). Children attending EMC ( $M = 414.72$ ;  $SD = 47.35$ ) scored significantly higher in attention ( $t(28) = -2.397$ ;  $p = .023$ ,  $r = .413$ ) as children not attending EMC ( $M = 372.67$ ;  $SD = 46.65$ ). In visual memory children attending EMC showed a tendency to outperform their not attending counterparts ( $U = 73$ ,  $p = .072$ ,  $r = .323$ ), see Table 2 for descriptive statistics.

### 3) Correlations between musical and cognitive abilities.

Music production abilities were significantly related to intelligence, spatial ability, language abilities (phonological awareness and verbal memory), visual and auditory attention and visual and auditory memory. For more details see Table 3.

**Table 3. Correlations between music production abilities and specific cognitive abilities.**

	production total score		singing		rhythm		metre	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
general knowledge	.418	.024	.409	.025	n.s.	n.s.	.568	.001
lexicon	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.380	.035
phonological awareness	.522	.004	.496	.005	.571	.001	n.s.	n.s.
verbal memory	.335	.076	.345	.062	n.s.	n.s.	n.s.	n.s.
verbal memory immediate recall	.345	.067	.367	.046	n.s.	n.s.	n.s.	n.s.
spatial ability	.406	.029	.332	.072	.398	.030	.340	.062
intelligence	.411	.027	.390	.033	n.s.	n.s.	.452	.011
visual attention	.415	.028	.372	.047	.373	.046	n.s.	n.s.
omission errors	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-.031	.092
auditory attention	n.s.	n.s.	.352	.046	n.s.	n.s.	n.s.	n.s.
visual memory	.499	.006	.439	.015	.504	.005	n.s.	n.s.
auditory memory	.374	.045	.413	.023	n.s.	n.s.	n.s.	n.s.

*Note.* Production total score = total test score of music production abilities. Singing = memorize and sing a song. Rhythm = replay a given rhythm. Metre = metre execution.

Music perception abilities were significantly correlated to intelligence, spatial ability, language ability (phonological

awareness and verbal memory), visual and auditory attention and auditory memory. The negative relation to visual continuity in the sense of fluctuation range indicates that children with higher music perception abilities show lower scores in fluctuation range implying achievement continuity. In addition to these correlations, which were the same as for music production an association of music perception and sensorimotor- function was revealed. For more details see Table 4.

**Table 4. Correlations between music perception abilities and specific cognitive abilities.**

	perception total score		tonal		rhythm	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
general knowledge	.390	.030	n.s.	n.s.	.446	.012
lexicon	.564	.001	.551	.001	.450	.011
phonological awareness	.412	.021	n.s.	n.s.	.509	.003
verbal memory	.321	.079	n.s.	n.s.	.380	.035
verbal memory immediate recall	.337	.064	n.s.	n.s.	.399	.026
spatial ability	.492	.005	.399	.026	.484	.006
intelligence	.585	.001	.511	.003	.534	.002
visual attention continuity	n.s.	n.s.	-0,339	.067	n.s.	n.s.
auditory attention	n.s.	n.s.	n.s.	n.s.	.374	.038
sensorimotor -functions	.325	.074	n.s.	n.s.	.391	.030
auditory memory	.306	.094	n.s.	n.s.	.383	.034

*Note.* Perception total score = total test score of music production abilities. Tonal = tonal perception score. Rhythm = rhythm perception score.

4) *Self-concept of ability.* In two of the four scores of self-concept of ability (criterial, individual, social, absolute) a significant difference between children attending and not attending EMC in favour of the children attending EMC was found, see Table 2 for statistics. In criterial self-concept of ability children attending EMC reported higher scores than children not attending EMC ( $t(29) = -2.418, p = .022, r = .410$ ). Additionally children with EMC reported higher scores in absolute self-concept of ability ( $t(29) = -2.1, p = .045, r = .434$ ).

Taken together after 33 months of attending the extended music curriculum differences, in favour of the musically trained group, were found in music production ability, language abilities, visual attention, visual memory and criterial and absolute self-concept of ability. These significant differences were not due to any confounding variable like intelligence, socioeconomic status and extracurricular schooling. Furthermore, a variety of significant correlations between musical and cognitive abilities were revealed. After a long period of music training several differences in cognitive

abilities could be observed. In attention and memory former (Study 1) significant correlations turned to group differences, indicating that the amount of time in music training plays a crucial role. With ongoing music training the effect on cognitive abilities got stronger and several cognitive abilities got affected. In order to make sure, that the increasing impact of music training on cognitive abilities and self-concept of ability is not due to any specific condition in the second sample, it is necessary to follow the participants of the first sample (Study 1). The further observation of the participants in Study 1, as their music training is ongoing, will give us insight in the development of relations between music training and cognitive abilities and their causal relationship.

## IV. Study 3

### A. Method

1) *Participants.* 34 children (21 girls) from the original sample in Study 1 were retested after one further year of music instruction. The participants were aged between 10 years and 5 months and 12 years and 7 months ( $Md = 11$  years; 1 month). 14 children (10 girls) by now participated for about 15 months in the extended music curriculum. From the group not attending EMC a nearly equal amount of boys (9) and girls (11) participated in the study. All in all 75.5% from the original sample participated in the retest after one year.

2) *Measures.* Not every testing procedure, formerly used in Study 1, was applied again. No measures of intelligence, spatial ability, sensorimotor-function, visual and auditory memory were administered. These tests will be applied again at future time points in the longitudinal study. In case parallel test versions seemed mandatory (music production-singing a song, auditory attention and verbal memory) parallel versions were used. For music production a new song version was composed, for auditory attention the target and distractor colours were changed and for verbal memory target list C was used instead of target list A.

Extracurricular schooling and socioeconomic status was again assessed by a questionnaire designed by the authors. Music production and perception abilities were measured with the music screening for children (with new song) by Jungbluth and Hafen (2005) and the Advanced Measure of Music Audiation (Gordon, 1989). Phonological awareness was measured with three subtests from the BAKO (Basiskompetenzen für Lese- und Rechtschreibleistungen; Stock, Marx & Schneider, 2003). Attention was tested using the auditory attention and response set from a neuropsychological test battery with changed target colours (NEPSY; Korkman, Kirk & Kemp, 1998) and a more visual aligned form of attention was measured by the attention and stress measurement “d2” (Brickenkamp, 2002). Verbal memory was assessed with a list learning (target list C instead of A) procedure (Helmstaedter, Lendt & Lux, 2001). The self-concept of ability was measured with a questionnaire (Skalen zur Erfassung des Schulischen Selbstkonzeptes; Schöne, Dickhäuser, Spinath & Stiensmeier-Pelster, 2002) assessing criterial, individual, social and absolute self-concept

of ability. The four self-concept of ability scores differ with respect to their benchmarks.

## B. Results and Discussion

Once again assumptions for parametric testing were verified. In case of violation of these assumptions appropriate nonparametric tests were used.

1) *Musical and specific cognitive abilities.* Statistics for the group comparisons are provided in Table 5. After 15 months attending and not attending EMC no significant differences between children attending and not attending EMC was found in music perception abilities. Music production scores are currently analysed therefore no results concerning music production could be reported.

**Table 5. Mean and standard deviation for control variables, music and cognitive abilities and self-concept of ability in children attending and not attending EMC.**

	10- to 12-year-olds			
	EMC		no EMC	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
music perception	50.93	6.07	49.30	9.06
phonological awareness **	22.00	4.98	16.75	5.12
verbal memory immediate recall #	6.86	1.96	8.05	1.99
verbal memory learning efficiency *	6.79	1.98	5.32	1.95
visual attention overall error #	5.21	3.29	8.45	6.71
visual attention continuity *	11.71	3.75	13.95	3.52
critical self-concept of ability #	59.14	8.78	54.00	8.25
social self-concept of ability *	59.29	10.59	51.15	6.57
absolute self-concept of ability *	58.29	10.37	51.35	8.75

*Note.* EMC = attending extended music curriculum. no EMC = not attending extended music curriculum. # $p < .1$ , two-tailed. \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed.

Regarding the specific cognitive abilities significant differences between children attending and not attending EMC were found for language and attention abilities in favour of the children attending extended music curriculum.

Children attending EMC ( $M = 22.00$ ;  $SD = 4.98$ ) scored significantly higher in phonological awareness ( $t(32) = -2.977$ ,  $p = .006$ ,  $r = .466$ ) as children not attending EMC ( $M = 16.75$ ;  $SD = 5.12$ ). In verbal memory children attending EMC showed significantly higher scores than children not attending EMC in learning efficiency for verbal material ( $U = 79.5$ ,  $p = .047$ ,  $r = .346$ ). In immediate recall for verbal material a tendency was found for children without EMC to score higher than children with EMC ( $U = 88$ ,  $p = .097$ ). Thus, for phonological awareness the former tendency (Study 1) changed into a

significant difference between trained and untrained children and the already existing difference in learning efficiency persisted. The surprising significant difference in immediate recall that children without EMC scored higher in immediate recall than children with EMC, found in Study 1 started disappearing. Additionally first differences in the attention scores were observed. Children not attending EMC showed the tendency to make more errors in visual attention than children attending EMC ( $U = 93$ ,  $p = .099$ ,  $r = .280$ ). Furthermore children attending EMC outperformed not attending children in the continuity of their visual attention achievement ( $U = 85$ ,  $p = .053$ ,  $r = .333$ ), see Table 5 for descriptive statistics. The higher score of the children without EMC indicates that their fluctuation range was higher thus achievement was not as continuous as for the children with EMC.

### 2) Correlations between musical and cognitive abilities.

Music perception abilities were significantly negatively correlated to overall errors in visual attention ( $r = -.343$ ;  $p = .047$ ) and in particular to omission errors in visual attention ( $r = -.369$ ;  $p = .032$ ). A marginal association between delayed recall of verbal material and music perception was found ( $r = .304$ ;  $p = .085$ ). The tonal score of music perception was marginally negatively correlated to omission errors in visual attention ( $r = -.294$ ;  $p = .091$ ). Rhythm perception ability was significantly related to phonological awareness ( $r = .362$ ;  $p = .042$ ), delayed recall of verbal material ( $r = .386$ ;  $p = .026$ ) and marginally correlated to verbal memory ( $r = .316$ ;  $p = .073$ ). Significant negative correlations between rhythm perception abilities and overall errors in visual attention ( $r = -.375$ ;  $p = .029$ ) and omission errors in visual attention ( $r = -.399$ ;  $p = .019$ ) were revealed. The surprising positive relation between errors in auditory attention and music perception, found in Study 1, disappeared.

3) *Self-concept of ability.* In three of the four scores of self-concept of ability differences emerged. In critical self-concept of ability children attending EMC showed a tendency to report higher scores ( $t(32) = -1.744$ ,  $p = .091$ ,  $r = .295$ ) than children not attending EMC. In social self-concept of ability musically trained children reported significantly higher scores than untrained children ( $U = 78$ ,  $p = .027$ ,  $r = .378$ ). Children attending EMC scored significantly higher in their reported absolute self-concept of ability than not attending children ( $t(32) = -2.108$ ,  $p = .043$ ,  $r = .349$ ), see Table 5 for statistics. The self-concept of ability scores that had not differed at the first time of testing differed now in criteria and absolute self-concept of ability, the same elements like in Study 2 and additionally differed in social self-concept of ability.

In summary, after 15 months of attending the extended music curriculum, we found significant differences, in favour of the musically trained group, in language ability, attention and self-concept of ability. Furthermore music perception was correlated to phonological awareness, verbal memory and delayed recall of verbal material (language ability). A negative relation between music perception and errors in visual attention was found. Regarding the self-concept of ability differences between children attending and not attending EMC

were found for criterial, social and absolute self-concept of ability. In all three measures children attending EMC reported higher self-concepts of ability. The longitudinal testing of the groups of Study 1 revealed that with more music training the strength of former relations increased or former tendencies changed into significant differences. Already existing differences persisted and contra intuitive results disappeared. Even new differences (self-concept of ability), for which the amount of music training seems to be crucial, emerged.

## V. Conclusion

The aim of these studies was to examine the relation between musical training and / or musical ability and specific cognitive abilities in a cross sectional and longitudinal manner.

The relation between specific musical abilities, such as music perception and production, and cognitive abilities was also investigated. To this end children with different amounts of music training in comparison to musically untrained children were tested and confounding variables like intelligence, socioeconomic status and extracurricular schooling were controlled. Additionally the self-concept of ability was measured to investigate a possible mediator of the positive effect of music on cognitive abilities.

In Study 1 9- to 11-year-old children, who had just started music training, were compared to their untrained counterparts in musical and cognitive abilities and self-concept of ability. The results indicate that, as soon as music training starts effects on musical and cognitive abilities, but not on self-concept of ability occur (Study 1). The positive effect of music training on cognitive abilities can not be attributed to confounding variables like intelligence, socioeconomic status or extracurricular schooling.

In Study 2 11-to 14-year-old children, participating for more than two years in music training, were compared to untrained children in musical and cognitive abilities and self-concept of ability. After longer periods of music training (Study 2) the effects on cognitive abilities were stronger and a variety of different cognitive abilities were affected. Furthermore, the self-concept of ability was influenced by music training and so might account as one possible explanation for the positive effects of music training on cognitive abilities. Since some cognitive abilities were improved before the self-concept of ability is affected by music training, the self-concept of ability could not be the only mediator. Self-concept of ability might be important for beneficial effects that evolve with ongoing training, like differences in attention, for example.

In Study 3 the children from Study 1 (now 10-to 12-years-old) were retested in musical and cognitive abilities and self-concept of ability, a year after the first testing session. With ongoing music training (Study 3) expected differences (language ability, attention) between trained and untrained children occurred. Contra intuitive findings (higher scores for untrained than trained children in immediate recall of verbal material), revealed in the first testing session, disappeared. So these longitudinal findings add evidence to the assumption that the direction of the relation is from music training to cognitive ability and not vice versa.

In these three studies a relation between music training and / or musical ability and language abilities like phonological

awareness and verbal memory was encountered. Consistent with earlier results by Anvari, Trainor, Woodside and Levy (2002) phonological awareness was related to music abilities, remarkably to both music production and perception abilities. After a short period of music training (Study 1) phonological awareness was related to music production, but with ongoing training (Study 3) a relation to music perception was also found. In the group of children with the longest music training period (Study 2) phonological awareness was correlated to music production and perception. Also effects of music training and / or musical ability on verbal memory, like Ho, Cheung and Chan (2003) encountered, were found consistently over all three studies. Also the disappearance, due to longer periods of music training, of reverse effects, meaning that musically untrained children scored higher in immediate recall in Study 1 could be observed. In contrast to findings from Ho, Cheung and Chan (2003) we revealed a marginal significant effect of music training on visual memory. This effect only occurred in the group with the longest period of music training (Study 2).

In accordance with Brochard, Dufour and Després, for example, we found effects of music training on spatial ability. In Study 1 musically trained children displayed higher spatial abilities than untrained children. Additionally relations between musical and spatial ability were found. In Study 3 a relation to rhythm perception abilities was revealed and in Study 2, after the longest period of music training relations to music production and perception was found. Moreover, spatial ability was related to both overall scores and all the subtests of music production (singing a song, replay a rhythm, metre execution) and music perception (tonal, rhythm). Similarly to Scott's (1992) results we found a relation to attention. This relation emerged with ongoing training and notably the revealed relation between music abilities and attention was found for both, auditory and visual attention. The results for self-concept of ability were noteworthy. After a few months (Study 1) of music training no differences in any measure of self-concept of ability could be found. However in the group with the longest music training significant differences in criterial and absolute self-concept of ability occurred. This led to the expectation that with ongoing training the effect of music on self-concept of ability arises. In line with expectation in Study 3 tendencies of a higher criterial self-concept of ability in musically trained children was found. Furthermore, absolute and social self-concepts of ability were significantly higher in children with music training. Using self-concept of ability as an approach to explain positive effects of music on cognitive abilities would be promising. There has been research about positive effects of music on self-concept or self-worth, but to our knowledge not to self-concept of ability.

In accordance to other longitudinal studies (Moreno et al., 2009), we found music training effects in language ability, adding evidence to proposed hypothesis. Additionally we broadened the cognitive abilities, under longitudinal investigation with respect to music training; especially the self-concept of ability is an interesting new candidate for further research.

Limitations to these findings are probably selection effects due to dropout in longitudinal research. Furthermore, participants were not assigned randomly to the music training, this could result in possible selection effects. We accounted for



that by measuring the control variables (intelligence, socioeconomic status, extracurricular schooling). This should rule out selection effects or alternative explanations. The studies added evidence to the hypothesis that the direction of the relation between music and cognitive abilities is from music training to positive effects on cognitive abilities. Additionally it is important for future research to carry out more music training experiments with random assignment and reasonable control groups to consolidate the knowledge about the causal relation between music and cognitive abilities.

Taken together we found a positive effect of music training on cognitive abilities. This effect is presumably directed from music training to cognitive abilities. Thereby the amount of training is important for the variety of cognitive abilities that are affected. A possible mediator for some cognitive benefits is the self-concept of ability.

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