

MONOGRÁFICO**Musical and cognitive abilities in children from disadvantaged backgrounds****Habilidades musicales y cognitivas en niños/as de entornos desfavorecidos**Graça Boal-Palheiros¹

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Abstract

Human beings are born with several abilities which are amenable to change. A growing number of studies have focused on the relations between musical and cognitive abilities but research with children from disadvantaged communities is scarce. This study explored the relations between musical and cognitive abilities in disadvantaged children. Participants were 169 children from deprived neighborhoods, attending the second year of primary education in public schools that do not offer music education. Children's musical abilities (perception) were measured with the Melody, Rhythm, and Memory tests of Montreal Battery for the Evaluation of Musical Abilities and their cognitive abilities, with five WISC-III subtests (Similarities, Vocabulary, Cubes, Picture Arrangement, and Digits). Parental level of education was obtained from a questionnaire on the socio-economic status of children's families. Results revealed (1) few and weak correlations between musical and cognitive abilities; (2) stronger correlations of Socioeconomic Status (SES) with cognitive than with musical abilities; (3) digit span predicts all musical abilities; 4) a clear factorial distinction between musical and cognitive abilities. Overall, results suggest that disadvantaged children's musical and cognitive abilities, as measured by the present instruments, are partly independent regarding processing components.

Key words: Musical ability; cognitive ability; children; socio-economic status.

Resumen

Los seres humanos nacen con habilidades que pueden sufrir cambios. Hay varios estudios que se centran en las relaciones entre las habilidades musicales y las cognitivas. Sin embargo, la investigación de esta relación entre niños/as desfavorecidos/as es escasa. Este estudio ha analizado las relaciones entre habilidades musicales y cognitivas en niños/as en contexto de exclusión socioeconómica. En él, han participado 169 niños/as de segundo año de Educación Primaria de escuelas públicas sin educación musical. Sus habilidades musicales (de percepción) se midieron con las pruebas de Melodía, Ritmo y Memoria de la *Montreal Battery for the Evaluation of Musical Abilities*, y sus habilidades cognitivas con cinco subpruebas de WISC III (Analogías, Vocabulario, Cubos, Ordenamiento de Historias y Retención de Dígitos). El nivel de educación de los progenitores se obtuvo a partir de un cuestionario sobre el nivel socioeconómico (SES) de las familias. Los resultados revelan (1) pocas y débiles correlaciones entre habilidades musicales y cognitivas; (2) correlaciones más fuertes de SES con habilidades cognitivas que musicales; (3) retención de dígitos predice todas las habilidades musicales; (4) una clara distinción factorial entre habilidades musicales y cognitivas. Nuestros resultados sugieren que las habilidades musicales y cognitivas de los/as niños/as desfavorecidos/as, medidas con estos instrumentos, son parcialmente independientes en componentes de procesamiento.

Palabras claves: Habilidad musical; habilidad cognitiva; niños/as; nivel socioeconómico.

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1. Introduction

Human beings are born with several abilities that they develop from an early age. The exceptional learning ability of humans allows newborns to adapt to the world. However, there are remarkable individual differences in learning ability (Stern, 2017). Development depends on genetic and environmental factors, such as genetic potential, maturation, environmental stimuli, enculturation, motivation to learn, socio-emotional interactions with family and peers, school education and specific training, among others. Cognitive psychology has explained how humans learn (general perspective), while the variation among individuals (differential perspective) has usually been the focus of psychometric approaches, but both lines of research have recently converged (Stern, 2017).

One line of research has focused on individual differences and the stability of children's abilities over time – cognitive abilities, including language (Bornstein *et al.*, 2016), musical (Kragness *et al.*, 2021) and other abilities. Children's abilities would depend more on their stable genetically driven potential than on training or environmental factors (Butkovic *et al.*, 2015; Schellenberg, 2011). These findings meet popular beliefs of talented, gifted individuals and revisits the ongoing debate of nature versus nurture. However, the idea that education and training would have a modest role in children's development might be viewed as disappointing in educational settings.

Another line of thought has focused on group differences, such as differences in age or musical training (e.g., musicians versus non-musicians) and has proposed that human abilities throughout the life span are plastic and amenable to change (Benítez *et al.*, 2021; Doidge, 2007). Psychological and neuroscientific approaches have pointed to numerous benefits of music education and training in different areas of children's development, exploring these effects on their non-musical skills (e.g., Ilari 2020; Swaminathan & Schellenberg 2019). Even if findings of near and far transfer effects are called into question, the concept of plasticity of human abilities is appealing, as it gives hope to potential benefits of education. Positive results of research have been welcomed by professionals of music education, as they strengthen the role of music in children's development and therefore its value in the school curriculum.

A growing number of studies have focused on both the development and the evaluation of musical abilities in children. The concept of musical ability remains somehow unclear in the literature, being referred to as musical aptitude, talent, intelligence, achievement, and musicality. It is accepted that musical ability includes several abilities, i.e., being able to perceive and understand music and to perform and create music in different ways, such as vocal or instrumental, as well as to engage in musical activities and have different preferences (Hallam, 2010; Shuter-Dyson, 1999). A crucial issue is that of evaluating children's musical abilities. The most common measures are tests of musical ability, which have produced a substantial area of research in Psychology of Music, alongside the psychometric approach in other areas.

The development of musical abilities in children from disadvantaged communities has not been much researched. Does the low socio-economic status of their families, their poor environment (i.e., less stimuli and opportunities for learning), affect their musical abilities as it affects their cognitive abilities (Rindermann & Ceci, 2018)? Characteristics of disadvantaged backgrounds (e.g., feelings of frustration, low level of affect, aggressiveness) are usually associated with children's low level of self-esteem and motivation, which in turn influence their teachers' expectations regarding their academic achievement (Ready & Wright, 2011). More

research is needed with children from these backgrounds, particularly in non-English speaking populations.

1.1 Concepts and evaluation of musical abilities

Concepts of musical ability and research on its evaluation have paralleled those of intelligence and cognitive abilities, and they have changed throughout the twentieth century from a single, unified genetically determined ability to a multi-faceted acquired ability influenced in part by environmental factors (Haier, 2017; Hallam, 2010).

Each of the various terms used in the literature has different meanings. Musical ability refers to what individuals can do musically; musical talent suggests heritability; musical aptitude suggests potential; musical achievement relates to what has been learned; musical intelligence is viewed as one of multiple intelligences (Gardner, 1983); and musicality implies affective dimensions such as music enjoyment (Boyle, 1992; Schellenberg & Weiss, 2013; Shuter-Dyson, 1999). In this paper, we adopt the term musical ability as the most comprehensive and inclusive, encompassing a range of cognitive processes and musical activities (Hallam, 2006).

Tests of musical ability for children have been used to decide whether their natural ability is appropriate for musical training and/or to identify deficits of musical ability (e.g., amusia). Usually, these tests evaluate mainly aural skills and consist of trials that ask if pairs of short melodies, rhythms and timbres are the same or different, i.e., how well listeners perceive, remember, and discriminate auditory musical sequences (e.g., Seashore 1919; Ullén *et al.*, 2014; Wallentin *et al.*, 2010). However, the nature and validation of musical ability tests can be biased by their authors' perspectives (Shuter-Dyson, 1999). Research has shown that musical aptitude tests serve limited purposes (e.g., Mota, 1997). Limitations of such measures should be considered as these do not capture the richness and complexity of an individual's musical ability. Nonetheless, in longitudinal studies, tests are an acceptable method that allows to objectively compare abilities at different timepoints of development. According to Karma (2007), although musical aptitude tests are often criticized for low ecological validity, in many cases ecological validity is not adequate as a measure of musical aptitude because it is necessarily multidimensional.

1.2 Relationships between children's musical abilities and cognitive abilities

A relevant question is whether musical ability is related to, or distinct from, other cognitive abilities. The literature has shown some interesting associations between musical ability and nonmusical abilities. For instance, good discrimination of sound units is required for good musical ability as well as for phonological awareness (to detect differences between phonemes). Correlations have been reported between children's musical ability and phonological awareness (Steinbrink *et al.*, 2019), reading skills (Anvari *et al.*, 2002; Strait *et al.*, 2011), language acquisition (Sallat & Jentschke, 2015) and, in hearing-impaired children, speech skills (Torppa & Huotilainen, 2019).

There is also evidence that children's general cognitive ability is associated with musical ability (Doxey & Wright, 1990; Hobbs, 1985; Norton *et al.*, 2005). Lynn *et al.* (1989) showed links between general intelligence and music ability, as measured by Raven's Progressive Matrices (Raven & Court, 1938) and Wing's Standardized Tests of Musical Intelligence (Wing,

1968), specifically, between factor *g* and three Wing's subtests (Chords analysis, Pitch change and Pitch memory). They demonstrated that the correlations between musical and cognitive abilities could be accounted for by a single factor, i.e., musical ability could be part of a general intelligence construct, or vice-versa. Other authors found associations between musical ability and specific cognitive abilities, such as spatial abilities (Anaya *et al.*, 2017; Nelson *et al.*, 1992) and working memory (James *et al.*, 2020). There is further evidence of the relation between musical ability and intelligence in studies that show associations between low musical aptitude and intellectual and learning disabilities (e.g., Braswell *et al.*, 1988; Couvignou & Kolinsky, 2021).

Associations between musical ability and general intelligence suggest that the two constructs are related. However, some studies show that those correlations are not strong ($< .50$) (e.g., Arenas *et al.*, 2016; Norton *et al.*, 2005; Swaminathan *et al.*, 2017; Swaminathan & Schellenberg, 2018; 2020). High- and average-IQ individuals may have low musical ability (Peretz, 2008; Sergeant & Thatcher, 1974) and some individuals with excellent musical ability have cognitive developmental disabilities (Treffert, 2009; Young & Nettelbeck, 1995).

Concepts like modularity (Peretz, 2009) and multiple intelligences (Gardner, 1983) suggest that musical ability is distinct from other cognitive abilities. Modularity proposes that the brain has different specialized modules that process different kinds of information (e.g., music, spatial features), and each module is independent from each other. The Theory of Multiple Intelligences proposes distinct types of intelligences (e.g., logical-mathematical, musical), though it continues to have low empirical support (Waterhouse, 2006), namely a lack of psychometric tests aimed at measuring the multiple intelligences.

In both perspectives, music and cognitive abilities are distinct from each other. Indeed, the lack of associations between musical and cognitive abilities has been reported. Kragness *et al.*'s (2021) 5-year longitudinal study with children showed no relation between musical ability and cognitive ability when children's differences at time 1 were controlled. However, children's working memory was related to their musical ability, presumably because working memory is crucial to process (perceive and remember) auditory sequences. In another study, Swaminathan and Schellenberg (2020), despite finding associations between IQ and musical ability, found that musical ability predicts language ability even when IQ influence is controlled. This suggests that IQ and musical ability have independent roles in language ability.

Overall, evidence suggests that musical and cognitive abilities are in part related to some degree. One way to investigate their relationship is by exploring their convergent or discriminant validation (Campbell & Fiske, 1959). Research has shown that children's cognitive abilities are related to socioeconomic variables – SES, family income, and parental level of education (Rindermann & Ceci, 2018; von Stumm & Plomin, 2015). If musical abilities are also related to SES, musical and cognitive abilities might be thought as convergent constructs. However, if they are not related to SES, they might be viewed as two divergent constructs.

There is evidence that higher SES is associated with longer duration of musical training and with better musical abilities in young adults (Swaminathan *et al.*, 2017; Swaminathan & Schellenberg, 2018). Musical abilities of children with low SES improved with training (Habibi *et al.*, 2018; Ilari *et al.*, 2016). Yet, the few studies exploring specific relations between musical abilities and SES in childhood found no such relation (Degé *et al.*, 2015; Swaminathan &

Schellenberg, 2019; 2020). This may be interpreted as additional evidence in favor of the independence of musical and cognitive abilities.

The present study investigates relations between musical and cognitive abilities in school-aged children by analyzing their cognitive and musical abilities, both general and specific. General and specific cognitive measures are correlated with musical measures. This permits to explore possible relations between different abilities, with special attention to memory, which seems to be the cognitive ability most related to musical ability (James *et al.*, 2020; Wallentin *et al.*, 2010). The study also examines the role of the children's SES on their musical and cognitive abilities. If our data indicates that both abilities are related to SES, we may conclude that musical and cognitive abilities are convergent. If only cognitive abilities are related to SES, then we may conclude that musical and cognitive abilities are partly independent.

2. Method

2.1 Sample

Participants were 169 Portuguese children ($M_{age} = 6.85$, $range = 6 - 8$, $SD = 0.45$; 84 girls and 85 boys), attending the second year of primary education. Ten classes were recruited from eight public schools in deprived areas in the city of Porto, which do not offer music education either as curricular or extra-curricular activity. This sample is part of a longitudinal study, which aims to evaluate potential effects of an active music education program on the development of children from disadvantaged communities. Data presented in this paper were gathered at the baseline of the study before the music education program began. Ethical procedures were followed. The study was explained to the children, parents or legal guardians, classroom teachers, and school leaders. Parents and teachers agreed to participate and have signed informed consent forms.

2.2 Instruments and Procedure

Musical abilities were assessed with the abbreviated version of the Montreal Battery for Evaluation of Musical Abilities (MBEMA) in childhood, which is suitable for assessing musical abilities in children 6-8 years of age and for identifying individual differences in music perception and memory in children from different musical and cultural backgrounds (Peretz *et al.*, 2013). We used MBEMA three subtests, Melody, Rhythm, and Memory, with 20 trials each (total of 60 trials). On the Melody and Rhythm subtests two short melodies were successively played on each trial, and children had to decide whether they were the 'same' or 'different'. In the Memory subtest, children heard a single melody on each trial and decided whether it had already been presented ('Yes') or was completely novel ('No'). The test was administered in group, in each classroom, and took about 30 minutes to complete. Before each subtest, instructions were given and two examples were presented, for which feedback was provided. Data analysis used the average correct responses for each subtest, and a total average correct (MBEMA total).

Children's cognitive abilities were measured with five subtests of the Wechsler Intelligence Scale for Children - Third Edition (WISC-III; Wechsler, 1991; Portuguese version by Simões & Ferreira, 2003): Similarities, Vocabulary, Cubes, Picture Arrangement, and Digits. In Similarities word pairs are presented and the child's task is to identify the similarity between the corresponding concepts ("What is similar between Red and Blue? Answer: They are colors");

Vocabulary consists of the oral presentation of words that the child is asked to define; in the Picture Arrangement task the child must order a set of pictures in a logical sequence; in the Cubes task the child uses cubes to replicate a set of two-dimensional geometric models; Digits consists of the oral presentation of number sequences that the child must replicate in the same order (direct sequence) and number sequences to be replicated in reverse order (so the child has manipulate information in her mind).

These subtests allowed to assess five children's specific cognitive abilities as well as to compute an abbreviated measure of IQ (with Similarities, Vocabulary, Cubes and Picture Arrangement), measures of verbal comprehension (Similarities, Vocabulary), perceptual organization (Cubes and Picture Arrangement), and digit span (Digits). All main five subtest raw scores were converted to standardized scores based on the WISC-III Portuguese version (Simões & Ferreira, 2003), and IQ measures were computed based on the normed scores. The Digits subtest can also be divided into auditory short-term memory (direct order) and working memory (reverse order). The idea that the WISC-III Digits subtest measures two different memory constructs was proposed after the WISC-III was published (see Kranzler, 1997). Subsequent versions of the WISC acquiesce that the digits' direct order and reverse order subtests are two distinct measures with their respective tables of standardizations. However, WISC-III is the more recent version adapted and validated for the Portuguese population. Therefore, analyses with auditory short-term memory and working memory were performed using the raw scores.

Socioeconomic status (SES) was measured according to parental level of education because previous research has shown that this variable is the most important SES predictor related to children's cognitive ability (Lemos *et al.*, 2011) as compared with others SES indices (family income, social status). From the parents' responses to a sociodemographic questionnaire, the level of education of the children's parents was grouped in six categories based on the Portuguese school system: 1) First Cycle (4 years of education); 2) Second Cycle (6 years); 3) Third Cycle (9 years); 4) Secondary (12 years); 5) Bachelor's degree; 6) Master's degree or higher.

3. Results

3.1 Data Analytic Plan

Firstly, descriptive statistics were calculated of MBEMA, WISC-III subtests and Parental Level of Education. Secondly, correlation coefficients between MBEMA, WISC-III subtests and Parental Level of Education were calculated. This approach permits to explore the relations between musical and cognitive ability, and whether both are related to SES. A set of stepwise regression models was performed to identify which cognitive abilities are more important for musical ability. Then, the Digits task was split in two raw measures – auditory short-term memory and working memory, to verify if there was a dissociation between the two, regarding musical ability. Finally, an exploratory factorial analysis (EFA) was performed to verify if children's abilities measured by MBEMA and by WISC-III can be split in two factors (music and cognition), or if all abilities saturate in just one factor.

3.2 Descriptive Statistics

Table 1 presents the descriptive statistics on MBEMA and WISC-III subtests. MBEMA scores varied widely among children, and three of them reached the perfect score on Rhythm.

Regarding WISC-III measures, two children reached the maximum VC index. Parental level of education was distributed as follows: 7.2% First Cycle; 9.9% Second Cycle; 28.3% Third Cycle; 34.9% Secondary; 19.7%; Bachelor's Degree; Master's degree or higher 0.7% (17 missing).

Table 1. MBEMA and WISC-III Descriptive Statistics

	Mean	SD	Min.	Max.
MBEMA (Total)	38.89	7.28	16	55
Melodic (max. = 20)	12.46	3.05	5	19
Rhythm (max. = 20)	13.54	3.24	5	20
Memory (max. = 20)	12.89	3.29	0	19
Abbreviated IQ	100.69	30.76	42	174
VC Index (max. = 200)	105.85	30.76	32	200
Similarities (max. = 19)	9.94	3.80	4	15
Vocabulary (max. = 19)	9.14	3.31	1	19
PO Index (max. = 200)	105.85	29.13	26	179
Cubes (max. = 19)	9.53	3.04	1	19
Picture A. (max. = 19)	10.42	3.86	1	19
Digits (max. = 19)	7.8	2.94	1	15

N = 169; VC = Verbal Comprehension; PO = Perceptual Organization

3.3 Correlation Coefficients

Correlation coefficients between musical abilities measured by the MBEMA and cognitive abilities measured by the WISC-III subtests are presented in Table 2. In general, all correlations are weak, between .16 and .32. Children's general musical ability (MBEMA total) and their specific musical abilities correlate with their IQ. Perceptual Organization is significantly associated with all musical abilities (between .19 and .28), whereas verbal comprehension is significantly associated with MBEMA total (.16) and Rhythm (.16), but not with Melody nor Memory.

Digits is correlated to all musical ability measures (between .23 and .32). This suggests that children's short term and working memory is important for musical ability. The two more verbally oriented subtests (Vocabulary and Similarities) were not significantly associated with any musical ability. Picture Arrangement was correlated with all musical ability measures (between .15 and .25), and Cubes was significantly correlated with Rhythm and Memory (between .18 and .21) but not with Melody.

Table 2. Correlations Coefficients between MBEMA and WISC-III

Variables	Abbreviated IQ	VC	PO	Digits	Vocabulary	Similarities	Picture A.	Cubes
MBEMA (Total)	.26**	.16*	.28**	.32**	.13	.14	.25**	.21**
Melody	.17*	.09	.19*	.25**	.10	.06	.23**	.07
Rhythm	.24**	.16*	.25**	.24**	.13	.14	.20**	.21**
Memory	.18*	.11	.20**	.23**	.06	.12	.15*	.18*

** $p < 0.01$; * $p < 0.05$; $N = 169$; VC=Verbal Comprehension; PO= Perceptual Organization

Correlations coefficients between children's abilities and Parental Level of Education are presented on Table 3. As expected, parental level of education is significantly correlated with all cognitive abilities measured by the WISC-III subtests (between .18 and .32), including the IQ measures (between .29 and .36). Interestingly, parental level of education is correlated with the MBEMA total (.19). However, the only MBEMA subtest significantly associated with parental level of education is the Memory subtest (.26). Children's abilities to discriminate Melodies and Rhythms did not correlate with parental level of education.

Table 3. Correlations Coefficients between Parental Level of Education, MBEMA and WISC-III

Variables	Parental Level of Education
MBEMA (Total)	.19*
Melody	.06
Rhythm	.10
Memory	.26**
IQ (Reduced)	.36**
V. C. (IQ)	.29*
P. O. (IQ)	.32**
Digits	.18*
Vocabulary	.26*
Similarities	.24*
Picture A.	.32**
Cubes	.20*

** $p < 0.01$; * $p < 0.05$; $N = 152$

VC = Verbal Comprehension; PO = Perceptual Organization

3.4 Stepwise Regression Models

A set of Stepwise Multiple Regressions were conducted (Table 4) with a criterion of entry ($p < .05$) and exclusion ($p > .10$). This method helps to decide what are the important variables to maintain in the model, and so to identify which cognitive abilities predict musical ability.

Children's general musical ability (MBEMA total) is significantly linked with Digits ($\beta = .26$, $p < .01$) and with Picture Arrangement ($\beta = .17$, $p < .05$). Regarding specific musical

abilities, Melody is also significantly linked with Digits ($\beta = .20, p < .01$) and with Picture Arrangement ($\beta = .17, p < .05$); Rhythm is significantly linked with Digits ($\beta = .20, p < .01$) and Cubes ($\beta = .16, p < .05$); Memory is only significant linked with Digits ($\beta = .23, p < .01$).

Table 4. Stepwise Regression models

Model	Dependent Variable	Independent Variables	β	Adjusted R ²
1	MBEMA (total)	Digits	.26**	.12
		Picture Arrangement	.17*	
2	Melody	Digits	.20**	.08
		Picture Arrangement	.17*	
3	Rhythm	Digits	.20**	.07
		Cubes	.16*	
4	Memory	Digits	.23**	.05

** $p < 0.01$; * $p < 0.05$; $N = 169$

3.5 Regression Models with Auditory Short-Term Memory and Working Memory

Previous results consistently revealed links between the Digits subtest (Digit Span) and musical ability. Since Digits can be split in two different memory constructs, Table 5 presents regression models by accounting the raw scores of auditory short-term memory ($M = 5.50, SD = 1.36, Min = 1, Max = 9$) and working memory ($M = 2.72, SD = 1.25, Min = 0, Max = 5$).

Model 1 shows that MBEMA total is significantly related to both short-term memory ($\beta = .28, p < .01$) and working memory ($\beta = .16, p < .05$). However, working memory is not significantly related to each MBEMA subtest, whereas short-term memory is related to all MBEMA subtests, Melody ($\beta = .21, p < .01$), Rhythm ($\beta = .25, p < .01$), and Memory ($\beta = .18, p < .01$).

Table 5. Regression models with raw memory measures

Model	Dependent Variable	Independent Variables	β	Adjusted R ²
1	MBEMA (total)	Short-Term Memory	.28**	.13
		Working Memory	.16*	
2	Melody	Short-Term Memory	.21**	.08
		Working Memory	.13	
3	Rhythm	Short-Term Memory	.25**	.07
		Working Memory	.07	
4	Memory	Short-Term Memory	.18*	.07
		Working Memory	.16	

** $p < 0.01$; * $p < 0.05$; $N = 169$

3.6 Factorial Analysis of all scores

An EFA using the Varimax rotation and Principal Component method was performed to explore latent common factors in children's musical and cognitive abilities. As can be seen in Table 6, the EFA revealed two factors, one that seems to capture the cognitive abilities measured by WISC-III, and another that seems to capture the musical abilities measured by MBEMA. However, it should be noted that the Digits task has similar loadings in both factors.

Table 6. Exploratory Factor Analysis

Abilities	Factors	
	Cognition	Music
Similarities (WISC-III)	.80	-.02
Vocabulary (WISC-III)	.76	-.01
Picture A. (WISC- III)	.67	.26
Cubes (WISC- III)	.51	.29
Digits (WISC- III)	.48	.44
Rhythm (MBEMA)	.12	.80
Melody (MBEMA)	.07	.74
Memory (MBEMA)	.10	.66
Eigenvalue	2.82	1.34
Variance (%)	35.24	16.79

KMO = .75

4. Discussion and conclusions

The main findings in this study suggest that children's musical and cognitive abilities are distinct. The overall correlations between musical abilities (melody and rhythm discrimination, memory for short musical phrases) and cognitive-related abilities (measured by 5 WISC-III subtests) were inexistent or weak.

A multivariate statistic approach through stepwise regressions revealed that digit span predicts all three musical abilities measured by MBEMA (Melody, Rhythm, and Memory). Within the perceptual organization abilities, we also found that Picture Arrangement predicts Melody, and Cubes predicts Rhythm. However, this relationship is not found in the literature. Children's verbal comprehension abilities are not relevant for their musical ability.

The predominant role of the Digits direct subtest on all musical abilities suggests that memory span is important. Analyses that account for the two constructs embodied in the memory span revealed that it is the short-term memory (i.e., quantity of information that can be sustained) that explains the relation between Digits and musical abilities, rather than the working memory (i.e., capacity to work on sustained information). Since Melody and Rhythm subtests of MBEMA

consist in comparing two successive auditory sequences, it makes sense that the children's capacity to sustain information is necessary to give correct responses. Yet, the Memory subtest of MBEMA correlation with short-term memory is weaker (.18). Thus, it is possible that Memory as measured by MBEMA is related more with long-term implicit memory, as listeners use implicit memory for musical features (Schellenberg *et al.*, 2019).

Regarding the partial independence of musical and cognitive abilities, our data shows that SES is related to all cognitive abilities. Yet it is related with only one musical ability, which is auditory Memory. The relations between SES and cognitive abilities are well documented (Rindermann & Ceci 2018). Thus, if musical abilities and cognitive abilities are related, SES should have been relevant for all musical abilities. The absence of relations between musical abilities and SES suggests that the family socio-economic status does not affect the children's musical abilities.

Further evidence for the distinction between musical and cognitive abilities was provided by the EFA, which reveals the dissociation between the MBEMA and the WISC-III subtests in two factors. However, the Digits subtest presents equal factor loadings in both factors. This is a relevant result, which suggests that digit span is different from other cognitive abilities. The literature has discussed whether digit span is related to other cognitive abilities and general intelligence, or whether it is a distinct construct (Ackerman *et al.*, 2005). Thus, digit span assessed by WISC-III seems to corroborate the digit span as a domain-general ability, which is used independently of the domain (Chein *et al.*, 2011).

The overall findings of this study are congruent with the perspectives of multiple intelligences (Gardner, 1983) and of modularity (Peretz, 2009). Gardner (1983) claimed that standard intelligence tests are too limited, as they do not evaluate other children's "intelligences" (abilities), and that human potential should not be reduced to linguistic and logical-mathematical abilities. However, standard intelligence tests continue to focus mainly on these abilities, ignoring other children's abilities such as bodily-kinesthetic, interpersonal, intrapersonal, and musical.

Another relevant issue is which and how children's musical abilities were measured. Research on the relations between children's cognitive and musical abilities has focused mainly on tests of music perception (e.g., Peretz *et al.*, 2013; Seashore, 1919; Ullén *et al.*, 2014; Wallentin *et al.*, 2010) and less on children's musical performance. For instance, Degé *et al.* (2015) found correlations between children's memory and rhythm production, but no other cognitive measures were used. In our study, music perception abilities are more related to short-term memory. Perhaps musical performance demands more cognitive abilities than listening to and perceiving music. Playing an instrument, for example, may involve not only cognitive components related to memory, but also visuospatial abilities (Anaya *et al.*, 2017). Future research should explore these questions.

Another issue relates to the different nature of musical and cognitive tests. Most musical tests rely mainly on the auditory information modality, and its temporal integration (see Shuter-Dyson, 1999), whereas cognitive tests are not specifically built for the auditory modality. One possible exception might be the digits' tasks (WISC-III), in which children must retain and work information that was aurally presented. In fact, this was the task most related to the children's musical abilities measured by MBEMA.

Our study explored the associations between musical and cognitive abilities on low SES children. The findings of weak relations between these abilities meet those from studies with

higher SES children (e. g. Swaminathan *et al.*, 2017; Swaminathan & Schellenberg, 2018; 2020), Our analyses suggest distinctive abilities, in favor of the perspectives of multiple intelligences (Gardner, 1983) and of modularity (Peretz, 2009). Therefore, it is important to recognize different abilities as different potentials that children can explore.

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