Impact of music education on the development of learning strategies, auditory discrimination, and working memory in adolescence

Short title: Cognitive impact of music education

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Impact of Musical Training in Specialised Centres on Learning Strategies, Auditory Discrimination and Working Memory in Adolescents

Abstract

The aim of this study was to analyse whether specialised musical training influences auditory discrimination, working memory, learning strategies and academic performance. Sixty students (30 with at least four years of musical training and 30 without) of the same socioeconomic level were compared. Significant differences were found between students with and without musical training in terms of learning strategies, working memory and academic performance (p= <.05). This study shows the benefits of musical training offered at specialised centres, the development of students' cognitive skills and the contributions of neuroscience to improving professional practice.

Keywords: Adolescence, Learning Strategies, Auditory Discrimination, Working Memory, Musical Training.

Introduction

Music is the art of combining and organising sounds to achieve a harmonious combination of frequencies and, therefore, a pleasant melody, which positively influences physiological and behavioural states (Panteleeva et al., 2017). Research in this field shows that the neuropsychological processes of music also affect the cognitive field (Bermell, 2004), increase attention and concentration for learning, facilitate neurorehabilitation (Jauset-Berrocal, Soria-Urios, 2018) and verbal, spatial and general cognitive abilities (Hannon and Trainor, 2007; Patel and Iversen, 2007). In this area, neuroscientific and educational psychology studies demonstrate the repercussions of musical activity on musicians in terms of improving brain plasticity by comparing musicians' functional and structural brain plasticity to that of non-musicians (Schlaug, Norton, Overy and Winner, 2005; Moreno, Marques, Santos, Santos, Castro and Besson, 2009); child and youth musicians also exhibit more advanced information processing (Stoesz, Jakobson, Kilgour and Lewycky, 2007) and intellectual, social and emotional development (Hallam, 2010; Campayo-Muñoz and Cabedo-Mas, 2017). In addition, recent studies have shown the extent to which neuroscience contributes to music development by providing strong arguments in favour of musical training (Peterson, 2011; Collins, 2013; Curtis and Fallin, 2014; Peñalba, 2017).

These findings, and others described in the following sections, served as a starting point for the present study on the analysis of musical activity, its brain processes and relationships to variables of auditory discrimination, working memory, learning strategies and academic performance.

Auditory discrimination

Neuroimaging studies show that listening to music involves different cortical and subcortical brain regions showing that music can facilitate the development of the neuropsychological and cognitive skills required for student learning (Kay, Meng, DiFrancesco, Holland, and Szaflarski, 2012; Koelsch and Skouras, 2014; Gray, Critchley, Koelsch, 2014).

One of these skills is auditory discrimination, which is used in the reception of sound, in understanding music and in the reproduction and creation of music, which requires activation of the auditory cortex of the temporal lobe of the brain, the supplementary motor area, the frontal gyrus and the brain areas related to memory for its recognition (Peretz, Gosselin, Belin, Zatorre, Plailly, Tillmann, 2009). The cerebral cortical organisation of music is analogous to the process illustrated by the speech processing model of Hickok and Poeppel (2007); on the one hand, there is a network (the ventral network) that links phonological sensory networks to conceptual representations while another network (the dorsal network) links phonological sensory networks to the motor areas responsible for the articulation of speech. These findings illustrate the relationship between auditory discrimination and language. In addition, phonological skills are necessary for decoding during reading (Rasinski & Lems, 2012; Resnick & Weaver, 2010)). To this end, grapheme-phoneme coding is performed by transforming graphic signs into sounds. Visual word recognition skills, sound identification, auditory perception, phonetic awareness and language are involved in these processes (Martin-Lobo, 2010, Cuetos, 2012).

On the other hand, auditory discrimination is necessary to recognising voices and listening to and processing oral information. Furthermore, this feature improves the understanding of speech sounds and their symbolic representation. In fact, strong connections between music and language have been identified, especially in relation to evolutionary background (Perlovsky, 2012), brain connectivity (Koelsch, Gunter, Wittfoth & Sammler, 2005) and skill transfer (Besson, Chobert & Marie, 2011). Some studies have highlighted the connection between music and language for communicative uses (Cross, 2009; Juslin & Laukka, 2003).

Along the same lines, neuroimaging studies have shown similarities and overlaps in syntactic processing between music and language (Jentschke & Koelsch, 2009; Jentschke, Koelsch, Sallat. & Friederici, 2008). Children learn the syntactic rules of language in their mother tongue from an early age and develop a detailed understanding of musical syntax (Lamont, 2016; Koelsch, 2013; Jentschke, Koelsch, Sallat & Friederici, 2008; Jentschke & Koelsch, 2009; Patel, 2008).

Music and language capacities share the same brain processing mechanisms (Fiveash and Pamer, 2014). Listening to a song activates the auditory cortex for acoustic analysis and lyric recognition, activating areas related to the music lexicon, where we store information (Peretz, Gosselin, Belin, Zatorre, Plailly, Tillmann, 2009). Primary, secondary and frontal auditory areas are also involved in pitch **(**Peretz et al., 2009); the cerebellum, basal ganglia, premotor cortex and supplementary area are involved in rhythm development (Drayna, Manichaikul, De Lange, Snieder, Spector, 2001; Zatorre, 2001). These brain areas are also involved in the processes of reading and writing, language learning, and academic learning (Schellenberg et al., 2007).

Other studies demonstrate the benefits of practising music for learning other languages. For example, better pronunciation, speech production and language levels in a second language have been found in students with musical aptitude (Milovanov et al., 2010; Schellenberg et al., 2007; Stegemööller et al., 2008; Thain, 2010; Toscano-Fuentes, 2011; Kraus and Chandrasekaran, 2010). Recently, there have also been consistent findings of a relationship between musicality and second language phonological competence according to the accent faking paradigm (Coumel et al., 2019).

In short, the findings of the above studies and of neuropsychologically based research suggest that music can promote the development of not only musical skills but also the hearing, auditory discrimination, language, and cognitive skills necessary for learning.

Working memory

One definition of working memory defines it as the cognitive system that allows access to a limited amount of information to be retained in the service of processing complex information (Shipstead, Lindsey, Marshall & Engle, 2014). Working memory enables relevant goals and memories to be addressed and is associated with performance in different aspects of cognition, such as multitasking (Hambrick, Oswald, Darowski, Rench & Brou, 2010). In the case of music, scientific literature has found a relationship between musical training and working memory, for example, from differences between musicians and non-musicians in how they perform tasks corresponding to the phonological loop (Fiveash & Pamer, 2014).

Regarding the musical activity of singing, neuroimaging studies have found that different brain areas are involved in the recognition of familiar melodies such as the upper right and left temporal sulcus, planum temporale, the supplementary motor area and left infero-frontal gyrus (Peretzet al., 2009); moreover, bilateral motor areas are involved in the musical interpretation of rhythm coordination and organisation, spatial organisation and movement sequencing, together with auditory and premotor areas of the right hemisphere (Zatorre, Chen, Penhune, 2007).

Learning strategies and academic performance

Bermell (2004) found that the neuropsychological processes of music learning affect attention and concentration through their didactics; such processes also have an impact on general cognitive skills and on social and emotional skills (Hannon and Trainor, 2007; Patel and Iversen, 2007). For example, musical training enhances language processing due to the overlapping of the brain regions that process language and music (Patel, 2010, 2012). Furthermore, it has been proven that learning strategies of acquisition, codification, recovery and support (Román, 1994) are related to performance and have an impact on academic performance (Martin-Lobo, Martinez, De la Peña and Pradas-Montilla, 2016).

In line with these studies, the present study focuses on analysing a potential relationship between musical training and the development of these learning strategies and academic performance. In Spain, the musical education can study by two ways:

- In primary and secondary school: students receive one hour weekly of music education, covering general music concepts for cultural literacy. In some centres, they go deeper into learning the recorder, Orff percussion instruments and other newer ones such as the ukulele or boomwhackers.
- In conservatory or specialised music centres: students receive specific musical training as an extracurricular activity. In both, musical language, and the study of a specific musical instrument (piano, guitar, violin, etc.) are studied. The Conservatory has a regulated educational structure, with qualified teachers. The Conservatory studies in Spain has a total duration of fourteen years divided into three stages: four years of basic training, six years of professional training, and four years of higher education. Higher education is equivalent to a University Degree in the European Union. All these stages are independent of school education, not being compulsory studies.

From the results of the studies discussed above, we ask the following: Do children with musical training in specialised centres have better auditory discrimination, working memory, learning strategies and academic performance than children without musical training. The present study expands the literature in this area of research, enriches it with contributions from neuroscience, and proposes improvements for professional practice and academic performance

This study will evaluate different neuropsychological variables, including auditory discrimination, working memory, and learning strategies, as well as academic performance in adolescence. Our aim is to analyse whether musical training provided through specialised centres can improve auditory discrimination, working memory and strategies related to academic performance. Establishing the relevance of musical training to brain development could help support the use of music to maximise its benefits for cognitive skills and improve teaching.

To this end, we compared two groups of participants (12 to 14 years old), a group with musical training from a specialised centre and a group with no formal musical training. Our specific objectives were as follows:

- Analyse possible differences between the two groups in terms of learning strategies.

- Analyse possible differences between the two groups in terms of auditory discrimination.
- Analyse possible differences between the two groups in terms of working memory.
- Analyse possible differences between the two groups in terms of academic performance.
- Analyse correlations between academic performance, auditory discrimination, learning strategies and working memory.

Methodology

- *Participants*

A comparative post-hoc design was used for this study. The sample included 60 Spanish students of both genders aged between 12 and 14 in the first and second years of compulsory secondary education. Participants with specific educational support needs (an intellectual disability, autism spectrum disorder, attention deficit disorder or others) were excluded.

The sample was composed of two groups (not random): a group with no musical training consisting of 30 students who had never received formal musical training at school and a group of 30 students who had received formal musical training for four years outside of the school system (all attending the same music centre) and for at least 2 hours per week to learn to play a musical instrument.

The four schools where the participants attended as the specialised music centres are located in Pozoblanco (province of Cordoba, Spain). Regarding the sociocultural context (Valle de los Pedroches), the schools are attended by students from various surrounding villages are of the same socioeconomic level, since on average, the economic profiles of the participants' families are based in the agricultural sector rural. The participants in the two groups come from the same social context.

Descriptive data for the two groups are shown in Table 1. The two groups are comparable in terms of age and sex.

INSERT TABLE 1

- *Instruments*

a) Learning Strategies

ACRA Learning Strategies Scale (Román & Gallego, 1994) was used to measure students' learning strategies. The ACRA scale is a questionnaire that refer to one of the following learning strategies:

- Information acquisition scale (20 items): evaluates processing strategies that favour attention control and those that optimise repetition processes.

- Information coding scale (46 items): assesses three groups of strategies (mnemonic, development and organisation of information).

- Information retrieval scale (35 items): evaluates search and response generation strategies.

- Processing support scale (35 items): assesses metacognitive, affective and social strategies

After obtaining raw scores, they were transformed into percentile scores.

The indicators of validity and reliability obtained are quite acceptable for the secondary education students with which they have been validated.

b) Working memory

Digit Span subtest (WISC-IV) (Weschler, 2005) was used to evaluate working memory, which dictates a series of numbers to the participant and then asks the participant to repeat them. The numbers are grouped into sets that become increasingly longer and, therefore, more complex to remember. This procedure is repeated in the same (direct) order and in reverse order. Each correct response is scored with 1 point. The highest score that can be obtained from this scale is 16.

c) Auditory discrimination

To measure auditory discrimination, the Phoneme Articulation subtest of the Dyslalia Assessment Test (PAF) was used (Vallés Arándiga, 1990). This test involves dictating 28 pairs of acoustically similar syllables and words and then asking the participant to repeat them. The score reflects the number of failures made in 28 elements.

Finally, we asked the participating schools to provide the average grades of the participants for the academic year (for the first and second semesters). This average was valued on a scale of 0 to 10 points. The subjects taken by the students in these two academic years are as follows:

- Natural Sciences
- Social Sciences, Geography and History
- Spanish Language and Literature
- Mathematics
- Foreign Languages
- Plastics
- Music
- Technology
- Religion or Alternative Subjects
- Second Foreign Language or Mathematics and Language Reinforcement

- *Procedure*

For this study, permission was sought from the involved centres, and informed consent was given by the Director or the Director of Studies as appropriate. The ACRA scale was also provided, and the purposes of all tests and scales were explained. Once we had obtained signed copies of the consent form from the students' legal guardians, the schools each booked one classroom to conduct all of the tests over one day.

The participants completed a questionnaire asking for basic information such as their age, gender, study centre, and student number (to be matched to the list of academic results) and whether they had completed the last year of basic musical training. The students had unlimited time to complete ACRA scale. To avoid errors in the answers, we replaced scale options A, B, C and D with options *never or hardly ever, sometimes, several times and always.*

As the students completed the ACRA scale, they were individually taken to a different classroom to evaluate working memory and auditory discrimination.

Finally, to collect the students' academic results, each centre provided a list with student numbers and average grades to maintain the students' anonymity. The evaluation of all the tests took 70 minutes, and all of the participants took the tests in the same order.

- *Statistical analysis*

Descriptive statistics were performed by obtaining mean, standard deviation, N and percentage. To compare both groups of participants, a T-test for independent samples (age) and a chi-square test (gender) were applied.

For objectives 1 to 4, mean-comparison analyses (T-tests of independent samples) were carried out. The musical training of the subjects was selected as an independent variable: a group of subjects with no musical training and a group of subjects with specific musical training. The dependent variables of the study were learning strategies (the four scales), auditory discrimination (for which errors were counted), working memory (measured through the direct and inverse digit test) and academic performance. Cohen's d test was used to calculate the effect size.

For objective 5, Pearson's correlation coefficient was used. A 95% significance level was adopted ($p = <.05$). For all statistical analyses, the SPSS statistical package (version 21) was used.

Results

Objective 1: To study differences between the two groups in terms of learning strategies.

The results of the analyses show significant differences between the groups in acquisition, coding, retrieval and support ($p<.05$). Table 2 shows that the averages for the group with musical training from a specialised music centre are higher across all of the measured variables of learning strategies than those of the group with no musical training. Cohen's d test result indicates a moderate to large effect size.

INSERT TABLE 2

Objective 2: To study differences between the two groups in terms of auditory discrimination

The results show no significant differences between the groups for the auditory discrimination task, although the observed differences are close to reaching significance ($p=.086$) (Table 3). Cohen's d result indicates a moderate effect size.

INSERT TABLE 3

Objective 3: To study differences between the two groups in terms of working memory.

The results obtained from the analysis show significant differences for the part of the memory involved in the processing of the central executive (inverse digits) but not for the part of the memory that uses the phonological loop (direct digits). As shown in Table 4, the average for the group with musical training is higher in inverse digits than that for the group with no musical training. Cohen's d result indicates a moderate effect size for the variable inverse digits.

INSERT TABLE 4

Objective 4: To study differences between the two groups in terms of academic performance.

The results show significant differences between the two groups in terms of academic performance ($p<.05$) (Table 5) with higher grades found for the group with musical training. Cohen's d result indicates a large effect size.

INSERT TABLE 5

Objective 5: To study the relationship between academic performance and auditory discrimination, learning strategies and working memory.

The results show a significant relationship between academic performance and auditory discrimination (Table 6). This correlation is negative: a higher score in academic performance corresponds to fewer errors in auditory discrimination. Significant correlations were also found for three of the four scales of learning strategies ($p<.05$) (except for coding). No significant correlations were found for working memory.

INSERT TABLE 6

Discussion

Our results show significant differences between participants who have received formal musical training and those who have not. It is worth mentioning that all of the participants' scores are within the normal range for their age. Participants who had received formal musical training in specialised centres in rural areas used more learning strategies and achieved higher scores on working memory (central executive) tests and in general academic performance. Academic performance was related to auditory discrimination and the use of learning strategies.

Our first objective was to analyse potential differences between the two groups in terms of learning strategies (students with musical training vs. students with no musical training). Students who have received musical training use more developed learning strategies in acquisition, coding and metacognitive strategies (supporting variables) (Román, 2014). Our results are in line with other research such as that of Bermell (2004), which shows that the neuropsychological processes of music affect the cognitive field by improving attention and concentration during learning, cognitive skills and other specific intellectual skills of the verbal, spatial and general fields (Hannon and Trainor, 2007; Patel and Iversen, 2007) that influences in the academic performance.
Further studies, music students exhibit improved academic performance because they show flexibility in problem solving and perceptual speed (Helmbold, Rammsayer & Altenmüller, 2005). In addition, music students show improved long-term visual-spatial, verbal and mathematical performance (Moreno, Marques, Santos, Santos, Castro & Besson, 2009). González-Castro, Rodríguez, Cueli, Cabeza and Álvarez (2014) also highlight the relationship between music and cognitive aspects such as vigilance and attention, which are essential to performance in school tasks. In the emotional sphere, music also facilitates support strategies for emotional learning (Gray, Critchley, Koelsch, 2014; Koelsch and Skouras, 2014).

In a study by Nielson (1999), the learning strategies of two organ students were identified as they prepared a piece of music. The students used selection and organisation of information strategies and thus used a systematic procedure to learn the material. Later, Nielson (2001) studied the learning strategies of advanced conservatory students during practical sessions. The results indicate that the students used more self-regulatory skills in addition to having specific objectives, participating in strategic planning, using self-instruction and task strategies and being selectively supervised at a detailed level during practice. The students also exhibited metacognitive skills such as the ability to assess their own performance. In a later study, the same researcher found beliefs about knowledge acquisition control and knowledge simplicity to be significantly related to strategies (Nielsen, 2012). In addition, the advantages and disadvantages of using formal and informal musical training to acquire strategies and channel creativity have been recently studied (Kastner, 2020; Hess, 2020).

Learning strategies are cognitive skills that help improve academic performance, as learning is more effective. These findings are in line with the findings of Martín-Lobo, Martínez- Álvarez, Muelas, Pradas and Magreñán (2018) and Martín, García, Torbay and Rodríguez (2008), who suggested that academic performance is related to the use of strategies that facilitate meaningful and self-regulated learning as well as deeper cognitive processing that seeks to find applications for the content studied.

Our second objective was to analyse auditory discrimination differences between the groups. Our hypothesis predicted that students with specialised musical training would make fewer errors on the provided test due to high levels of auditory stimulation. Nevertheless, we could not find such differences, although margin error (5%) might be having an influence on results. Previous studies, such as Kraus and Chandrasekaran (2010), suggested that musicians develop the auditory system differently and have better auditory skills. This also fits in with the work of Marques, Moreno, Castro and Besson (2007), who found that musicians are more competent when required to quickly detect tonal changes in a foreign language.

Another objective was to study differences between the groups in terms of working memory. We expected to obtain higher scores for the group with specialised musical training than for that with no musical training. Our results partially support this hypothesis. The adolescents with musical training showed a greater mastery of the central executive than the participants with no musical training. Other studies corroborate these results but for other populations. Pallesen et al. (2010) conducted a study of two groups of adult musicians (a small sample) analysing memory stress and found that adults with musical training have better auditory working memory than those with only elementary training. Killough et al. (2013) demonstrated the same result for a population of musicians, Hansen et al. (2013) found this result for expert musicians, and Lu (2016) identified this result for adults, confirming the benefits of musical training for the expansion of working memory. Our study contributes to this work by showing that with the expansion of musical training in primary education, the benefits applicable from the start of secondary education can improve academic performance in later educational stages. Similar results are given by Roden et al. (2014), who evaluated working memory in 7- to 8-year-old children following an 18-month music programme and found that the students showed an increase in auditory information processing. Musical training favours the development of working memory from early childhood because music learning involves cognitive functions of coding, storage and retrieval associated with memory (Zuk, Benjamin, Kenyon & Gaab, 2014). For example, phonological memory has been found to be a predictor of pronunciation ability along with perception and auditory discrimination in children who begin learning music at an early age (Hu et al., 2012).

Along the same lines, it was found that musical training favours musical skills developing the mechanisms of verbal long-term memory in musicians (Franklin et al., 2008). Studies of individuals learning to play a musical instrument suggest that short and long-term memory are needed for comprehension, repetition, and the exercise of rhythm and sequences, which implies the activation of these processes at a conscious level until learning is automated (Soria-Urios, Duque y García-Moreno, 2011). The perception of musical tone has been shown to be a predictor of pronunciation when using a second language (Posedelet, 2011).

Finally, the effects of school musical training programmes on verbal and visual memory skills in primary school children have been examined, and significant improvements in verbal memory have been identified (Roden, Kreutz, and Bongard, 2012). From a study on instrumental training programmes, Roden et al. (2014) concluded that students with musical training show significant differences in working memory in terms of central executive, phonological loop and visuospatial agenda components; such individuals also exhibit improved cognitive functioning and overall performance.

For objective 4, our hypothesis predicted higher levels of academic performance for the group with musical training, and our results are in line with this prediction. Engaña (2008) observed stronger performance in subjects such as language and mathematics in children who were part of a junior orchestra with similar musical training using the SIMCE 2001 and PSU 2003 tests. Our findings are also in line with those reported by Reyes (2011), who studied 4000 primary school students from the community of Valencia (Spain). In this study, the author found children with artistic musical training to obtain better academic results than others while analysing the impact of musical training in subjects such as mathematics, language, sports, science and the arts. Such results also coincide with other recent studies carried out in other countries, such as Switzerland (Wetter, Koerner & Schwaninger, 2009), Canada (Cabanac, Perlovsky, Bonniot-Cabanac & Cabanac, 2013) and the United States (Kinney, 2008; Southgate & Roscigno, 2009).

Finally, for objective 5, the results show a significant correlation between academic performance and auditory discrimination and learning strategies. Regarding the correlation between academic performance and auditory discrimination, the relationship seems obvious, as Defior (2008) already demonstrated, showing that auditory discrimination is fundamental to the development of reading and writing skills. Rodríguez and Remesal (2007) also found a correlation between academic performance and learning strategies in university students. The authors observed higher academic performance in students with higher scores on learning strategies.

The main limitation of this study relates to the difficulty of finding participants with musical training from specialised centres. For this reason, we had to recruit participants from several schools to obtain a sample of the same socioeconomic level. According to a study carried out in the United States (Elpus, 2013), it is important to control demographic variables used in comparative studies such as the one we carried out (studying a single music centre, socioeconomic level, gender and ethnicity). We tried, as much as possible, to ensure that variables for our two study groups were homogeneous. Therefore, it may be advisable to carry out a similar study in a larger city (or several) to recruit participants from different music schools. This approach would help increase sample variability and geographical representativeness. Another limitation of this study concerns the academic performance variable used. This variable was calculated from the scores of students in different subjects and from different schools (although all of the schools studied are located in the same rural area and are of the same socioeconomic level). Variations in the qualification criteria of the different schools or teachers might have affected our results. As a final limitation, we must note our inability to control certain variables, such as the IQ scores of the participants and their prior cognitive skills, even though all of the involved students participated in schooling without difficulty and within the normal range. For this reason, we must be cautious in interpreting differences in the academic performance of the two groups studied even though participants from different schools were indiscriminately assigned to either group. It should be noted that the conclusions presented were already known in the scientific field, but it is always convenient to review the findings in different environments and at different times, to find new findings or errors from the past.

Finally, we believe that this study highlights the value of formal musical training and the relevance of including this subject in educational and academic contexts within the educational field and adopting neuroscience to improve learning.

The results of this study show significant correlations between musical training and learning strategies, working memory and academic results in adolescence. More specifically, we found that students with specialised musical training achieve higher scores on learning strategies and their subscales: acquisition, coding, recovery and support. We observed higher levels of auditory discrimination in the group with specialised musical training. However, these differences are not significant, possibly due to the influence of margin error (5%) on results. In addition, students with specialist musical training scored better on the inverse-digit subtest of the working memory scale, suggesting further development of the central executive. We observed better academic results for students in the group with specialised musical training. We found correlations between academic performance, auditory discrimination and learning strategies. To conclude, we highlight the relevance of neuroscience to music training from specialised centres. It would be desirable to promote musical training for students in all educational contexts given the data obtained and the scientific literature.

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Table 1. Descriptive data for the sample

Variables	**M**	**S.D.**	**T Test *(p)***
Age			
- Group with no musical training	12.60	.498	1.000
- Group with musical training	12.60	.498	1.000
	N	***%***	***Chi-square (p)***
Gender			
- Group with no musical training			
• Male	13	43.3%	
• Female	17	56.7%	
- Group with musical training			.284
• Male	9	30%	
• Female	21	70%	

Table 2. Differences between the two groups in terms of learning strategies

Variables	**M**	**S.D.**	**T test** ***(p)***	**Cohen's d**
Acquisition scale				
- Group with no musical training	56.33	34.20	.004*	.769
- Group with musical training	78.63	22.56		
Codification scale				
- Group with no musical training	51.23	29.50	.005*	.751
- Group with musical training	71.40	23.86		
Retrieval				
- Group with no musical training	38.66	29.95	<.001*	.996
- Group with musical training	66.03	24.74		
Support scales				
- Group with no musical training	32.96	25.27	<.001*	1.265
- Group with musical training	62.96	22.03		

Note: *significance p<.05

Table 3. Differences between the two groups in terms of auditory discrimination

Variables	**M**	**S.D.**	**Test (*p*)**	**Cohen's d**
Auditory Discrimination				
- Group with no musical training	5.06	2.21	.086	.447
- Group with musical training	4.20	1.58		

Note: *significance p<.05

Table 4. Differences between the two groups in terms of working memory

Variables	**M**	**S.D.**	**T test** ***(p)***	**Cohen's d**
Working memory (Direct digits)				
- Group with no musical training	10.43	2.35	.566	.148
- Group with musical training	10.10	2.10		
Working memory (Reverse digits)				
- Group with no musical training	7.73	2.14	.047*	.525
- Group with musical training	8.93	2.42		

Note: *significance p<.05

Table 5. Differences between the two groups in terms of academic results

Variables	**M**	**S.D.**	**T test (p)**	**Cohen´s D**
Academic results				
- Group with no musical training	6.21	1.37	.001*	.920
- Group with musical training	7.48	1.39		

Note: *significance p<.05

Table 6. Correlations between academic results, auditory discrimination, and working memory

Variable	**Academic results**	
	r	***p***
Auditory discrimination	-.339	.008*
WM direct digits	-.134	.308
WM reverse digits	.236	.069
Acquisition scale	.435	.001*
Codification scale	.239	.066
Retrieval scale	.303	.019*
Support	.424	.001*

Note: *significance p<.05; r = Pearson's correlation.