Original Article

https://doi.org/10.1590/2317-6431-2019-2156

Audiology Communication Research
ISSN 2317-6431

Influence of children's music learning on preschoolers' listening skills

Influência da musicalização infantil nas habilidades auditivas de pré-escolares

Evellyn Silva Azevedo de Jesus[1], *Isabella Monteiro de Castro Silva*[1]

ABSTRACT

Purpose: Verify the association between children's music learning and listening skills of temporal ordering and sound localization in preschoolers from 5 to 6 years old. **Methods:** 60 children of both genders, from 5 to 6 years and 11 months, participated in the study, 30 of the group with music training and the other 30 of the group with no music training. The participants of both groups were submitted to hearing screening, simplified auditory processing assessment and to the Pitch Pattern Sequence. The performance of each of the procedures was tabulated, being analyzed the possible correlations and associations between them, as, for example, dependent and independent variables such as group, gender and age. **Results**: The group with music training presented higher mean of scores than the one with no music training in the verbal and nonverbal sequential memory tests and on the verbal and nonverbal Pitch Pattern Sequence. The 5-year-old children of the group with music training got better results than the 5-year-old ones with no music training, getting right in more sequences. In the sound localization test, there was no difference between ages and groups. **Conclusion**: Preschoolers from 5 to 6 years old who participated in children's music learning presented better performance in the tests that evaluate the abilities of the verbal and non-verbal sequential memory and of the temporal ordering of three sounds when compared to the preschoolers who did not participate in the music learning. Therefore, the children's music learning positively influenced the listening skills of preschoolers from 5 to 6 years old.

Keywords: Listening; Child; Auditory perception; Hearing tests; Music

RESUMO

Objetivo: Verificar a associação entre musicalização infantil e habilidades auditivas de ordenação temporal e localização sonora em pré-escolares de 5 e 6 anos. **Métodos:** Participaram do estudo 60 crianças de ambos os sexos, de 5 anos a 6 anos e 11 meses, sendo 30 do grupo com treinamento musical e 30 do grupo sem treinamento musical. Os participantes de ambos os grupos foram submetidos à triagem auditiva, avaliação simplificada do processamento auditivo e ao teste Padrão de Frequência, em campo livre. Os desempenhos de cada um dos procedimentos foram tabulados, analisando-se as possíveis correlações e associações entre eles, como variáveis dependentes e variáveis independentes, como grupo, sexo e idade. **Resultados:** O grupo com treinamento musical apresentou média de acertos superior ao grupo sem treinamento musical, nos testes de memória sequencial não verbal e verbal, teste Padrão de Frequência não verbal e verbal. Sujeitos de 5 anos do grupo com treinamento musical obtiveram melhor desempenho, em relação aos sujeitos de 5 anos do grupo sem treinamento musical, acertando mais sequências. No teste de localização sonora, não houve diferença entre a idade e o grupo. **Conclusão:** Pré-escolares de 5 e 6 anos que participavam de musicalização infantil apresentaram melhor desempenho nos testes que avaliaram as habilidades de memória sequencial não verbal e verbal e de ordenação temporal de três sons, quando comparados aos pré-escolares que não participavam de musicalização. Portanto, a musicalização infantil influenciou positivamente as habilidades auditivas de pré-escolares de 5 e 6 anos.

Descritores: Audição; Criança; Percepção auditiva; Testes auditivos; Música

Study conducted at Curso de Fonoaudiologia, Faculdade de Ceilândia, Universidade de Brasília – UnB – Brasília (DF), Brasil.
[1]Curso de Fonoaudiologia da Faculdade de Ceilândia, Universidade de Brasília – UnB – Brasília (DF), Brasil.
Conflict of interests: No.
Authors' contribution: ESAJ participated in the conception, collection, interpretation of data, writing and revision of the scientific article; IMCS participated in the conception, data analysis, writing and revision of the scientific article.
Funding: None.
Corresponding author: Isabella Monteiro de Castro Silva. E-mail: isabellamcsilva@unb.br
Received: March 04, 2019. **Accepted:** June 24, 2019.

This is an open-access article distributed under the terms of the Creative Commons Attribution License.

INTRODUCTION

The auditory processing is not just the ability to perceive the absence or presence of sound, but also the ability of the central auditory system to receive, process and use auditory information, discriminate the sound, separate it from irrelevant noise, understand it and recognize it as familiar. This process involves a complex system of neurons that conducts the acoustic information, in the form of electrical impulses, to the primary auditory cortex, which has, as a feature, the ability to discriminate the sound as to its frequency, intensity, location and temporal aspects, such as the integration and temporal discrimination, temporal ordering and temporal masking[1]. The auditory skills of sound localization and sequential memory for verbal and nonverbal sounds can be assessed in individuals over 3 years old through the simplified auditory processing assessment[2].

Before birth the baby already perceives, identifies, reacts and stores in the memory the sounds of the fluids and movements of the organs that are part of the mother's organism, besides her voice and, after birth, the ambient sounds offer possibilities of interaction and internalization of auditory experiences. In addition, they make the record of the first experiences in memory that may be used or transformed in the future, shaping the perceptual choices[3].

Music is a combination of ear-pleasing sounds that can be enjoyed in human life from the fetal age. Auditory perception will help the children to understand the sound stimuli and their effects, especially regarding the frequency, duration, timbre and the intensity of sound[1,3]. One study investigated the behavior and memory of the fetuses that were exposed to an ascending and descending piano tune twice a day during the 35th, 36th and 37th weeks of gestation. It was concluded that the cardiac responses of fetuses exposed to the melody changed congruently to the piano melodies, experiencing increased heart rate in ascending melodies and decreased heart rate in descending melodies[4].

Temporal auditory processing consists of the perception of several sound stimuli within a certain time, this time being essential for the best capacity of auditory processing. It is subdivided into the areas of study of temporal resolution or discrimination, temporal ordering or sequencing, temporal masking and temporal integration. Frequency Pattern and Duration Pattern tests are currently the most widely used for the evaluation of temporal ordering ability[5,6].

Music is a temporal, perceptive and creative activity that promotes sensory, emotional, motor and intellectual stimulation. Musical intelligence is the listening capacity that individuals have to differentiate the meaning and importance of a set of rhythmically organized and sequenced sounds and to produce them as a means of communication. This intelligence appears very early in humans[7].

The central nervous system is flexible to changes arising from the listening experiences of an individual undergoing induced stimulation thanks to neural plasticity. Then, according to the critical period for the development, all contact with hearing stimuli present in the environment in the first years after birth may influence the auditory cortex response to sounds in the future[8]. Auditory training during childhood is related to an efficient coding of sounds in adulthood, justified by a "listening reserve" that has developed and matured by life-long auditory experiences[8].

Studies including young adults who did and did not take music lessons when they were children showed that the contact with a musical instrument promoted more efficient neural responses to the musical notes[9,10]. Other studies have also shown that the musical experience during the preschool phase can cause changes in the auditory processing, inferring that the experience with music before 7 years of age may favor cognitive, auditory, linguistic and appreciative development, especially of the temporal processing skills of the child exposed to music[11-13]. However, few studies related to the listening skills of preschoolers who perform musical training are found.

Considering that auditory behavior is developed over the years and that the musical training, as an acoustic experience, can shape specific perceptions during discrete intervals, the aim of this study was to verify the association between children's musical learning and listening skills of temporal ordering and sound localization in preschoolers from 5 to 6 years old.

METHODS

This is a quantitative observational, descriptive and cross-sectional study. Sixty preschoolers, male and female, aged from 5 to 6 years, participated in this research, divided into two groups: group with music training (GWMT) and group with no music training (GNMT), constituting a convenience sample. All the responsible people for the children signed the Informed Consent Form (ICF) and the participants affirmed and indicated their consent to participate in the Informed Consent Form (ICF). The study was approved by the Ethics Committee of the Faculdade de Ceilândia (Ceilândia College) - CEP/FCE, the research host institution, under No. 2,911,869.

The GWMT was composed of 30 preschoolers who participated in the Music for Children (Música Para Crianças, MPC) extension project of a public higher education institution once a week. The extension project receives babies from 6 months old for the first contact with rhythm and melodies. From the age of 4, there is an initialization in music theory, with early rhythmic reading and solfeggio, preparing the children to learn a musical instrument, which starts at 6 years for all instruments, except the violin, which starts at 4. Initially, the research proposal was presented to the principal and, later, contact was made with the teacher and the parents (of the students) of each participating class. The invitation and the terms of consent were directly delivered (person-to-person), when the meetings were scheduled to begin the collection. All GWMT collections were performed at the MPC project site, at a time previously agreed with the parents and the teachers of musical learning.

The GNMT was composed of 30 preschoolers, students from a public school in Ceilândia-DF who did not participate or had not participated in children's music learning or in any other musical activity. GNMT participants were recruited after a meeting with the teachers and the school principal to present the research objective. After the authorization, written invitations were sent on the agenda to the responsible people for the GNMT students, along with the terms of consent. GNMT collections were performed during the intervals of the pedagogical activities in the regular school, with the authorization of the teachers.

The GWMT inclusion criteria consisted of being from 5 to 6 years and 11 months and having participated for at least one year of music learning. The inclusion criteria of the GNMT were: being from 5 to 6 years and 11 months and not having

participated in music practice activities. Participants with any otological alterations during the evaluation period and/or with cognitive or neurological alterations reported by their parents or teachers, which could compromise the comprehension and performance of the evaluations, were excluded from the study. The procedures consisted of two individual sessions, lasting 20 minutes each, held in a quiet environment. Before starting the session, the procedures were clarified to the participant and to his/her responsible.

In the first session, a hearing screening with a pediatric audiometer, Interacoustics®, model PA5, was performed, maintained at 20 cm from the ear, to test the frequency thresholds of 500, 1000, 2000 and 4000 Hz frequencies, starting from the right ear. The normality criterion adopted was the "pass-fail" one, being "fail" when the individual did not answer at least one of the tested frequencies and "pass" when the individual obtained a response of 20 dBHL for all tested frequencies[14]. The procedure got started after biological calibration.

After the hearing screening, a simplified auditory processing assessment (SAPA) was performed to check the five-way sound localization skills, verbal sequential memory (VSM), nonverbal sequential memory (NVSM), and cochleopalpebral reflex (CPR) research. For the five-way sound localization test (top, right, left, front, behind the head), the participant was blindfolded and directed to point to which of the five directions perceived the presence of the sound stimulus emitted by the rattle instrument. The normality criterion adopted was to get right at least four of the five directions presented[2].

The CPR was also evaluated using the agogô instrument, strong-struck near the ear pavilion to trigger the blinking reflex. In the NVSM test, the examiner presented musical instruments of different timbre and acoustic aspects (reco-reco, shaker, coconut and rattle) to the participants for their prior recognition. Then three sequences of three instruments were presented to the 5-year-old children and three sequences of four instruments to the 6-year-old ones, all blindfolded. Participants were asked to memorize and arrange the musical instruments in the same order as the sequence heard. In the VSM test, three sequences of three syllables were presented for the 5-year-old students and four syllables for the 6-year-old ones, such as: [/pa/, /ta/, /ca/] or [/pa/, /ta/, /ca/ /fa/]. The participants were told to repeat them, respecting the order in which they were pronounced. The expected response criterion for the VSM and NVSM tests was: for 5-year-old children, it was expected to get right two sequences of three sound stimuli and, for the 6-year-old ones, it was expected to get right from two to three sequences of four stimuli[2]. The 5-year-old participants who got right all three sequences of three instruments and of three syllables were reevaluated with the addition of one instrument and one syllable.

In the second session, the Auditec® Children's Pitch Pattern Sequence (PPS) was performed to assess the temporal ordering, recognition, discrimination, tonal pattern sequence and temporal integrity skills. The tones were presented in free field, using a JBL® speaker, in a sequence of three tones which varied in frequency: high (1430 Hz frequency) or low (880 Hz frequency). Ten sequences with three tones each were presented, in which participants would have to reproduce humming (nonverbal response) and also ten sequences with three tones each, in which participants would have to name (verbal response), identifying as low or high the sequence heard. Children would have to get right at least eight sequences, equivalent to a percentage of 75%, reaching the reference value present in the literature for the age group above 7 years, above 75%[15], since there is no reference for children under that age.

The performances of each of the procedures were tabulated and the possible correlations and associations between the performances, as dependent variables and independent variables, such as group (GWMT/GNMT), gender and age were analyzed using the SPSS 20.0 statistical package, with tests according to the characteristics of the studied variables, including ANOVA and the Chi-square association test.

RESULTS

A total of sixty children participated in the study, with an equivalent distribution of the number of participants among the age, gender and group variables (Table 1). The music learning time in GWMT children ranged from 2 to 5 years, with an average of 4 years for children from 5 to 6 years old.

All participants presented cochleopalpebral reflex and responses to 20 dB in the hearing screening, as expected by the biological calibration. In the sound localization test there was no difference between the GWMT and GNMT groups, i.e., the number of subjects in both groups that passed or failed was similar in the distribution between the studied variables (Figure 1). The Chi-square test showed that there was an association between the performance on NVSM (p=0.001) and VSM (p=0.023) tests and the groups with and with no musical training. The GWMT presented a higher number of participants who passed in the NVSM and VSM tests with three and four instruments when compared to the GNMT (Figure 1).

Performance results on the NVSM and VSM tests, depending on the age by group, showed that 6-year-old participants of the GNMT and GWMT had better performance than the 5-year-old ones in both groups and that the GWMT participants got right in more sequences when compared to GNMT. However, the ANOVA result showed no difference between the 5 and 6 (years old) age groups, either in the NVSM test (p = 0.441) or in the VSM test (p = 0.381) (Figure 2).

The means of performance in the PPS, according to ANOVA, were statistically different between the groups, showing that GWMT had better performance than GNMT, both in verbal

Table 1. Characterization of the sample regarding age, gender and group variables

Age in Years	Group				Total
	Group with music training		Group with no music training		
	Female	Male	Female	Male	
5	8	7	7	8	30
6	7	8	8	7	30
Total	15	15	15	15	60

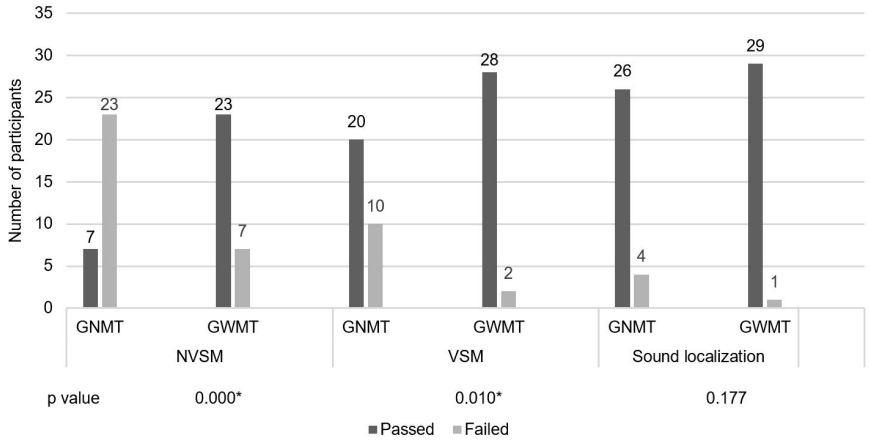

Figure 1. Performance of the participants in the simplified auditory processing assessment, considering the number of participants in each group with a "pass" result in each test. *Significant values (p<0.05) – Chi-square test
Subtitle: NVSM = Nonverbal sequential memory; VSM = Verbal sequential memory; GNMT = group with no music training; GWMT = group with music training

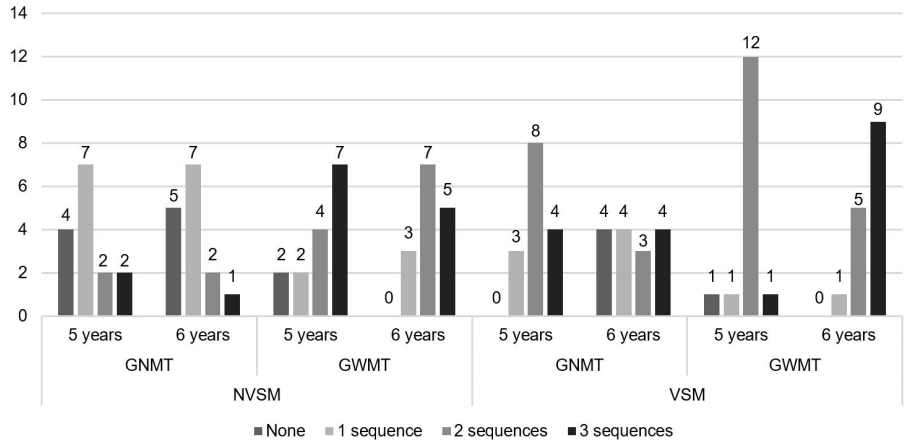

Figure 2. Distribution of the participants who got right the test sequences according to age and group
Subtitle: GNMT = group with no music training; GWMT = group with music training; NVSM = Nonverbal sequential memory; VSM = Verbal sequential memory

Table 2. Results of the nonverbal and verbal Pitch Pattern Sequence, by age and group

Tests	Groups	Age	Mean	Standard Deviation	N	Minimum	Maximum	p Value
Nonverbal PPS	GNMT	5	44	48.37	15	0	100	*0.003
		6	66.67	38.48	15			
		Total	55.33	44.47	30			
	GWMT	5	93.33	25.82	15	0	100	
		6	80	41.4	15			
		Total	86.67	34.58	30			
Verbal PPS	GNMT	5	6	18.44	15	0	90	*0.003
		6	19.33	30.58	15			
		Total	12.67	25.72	30			
	GWMT	5	33.33	42.87	15	0	100	
		6	46	39.79	15			
		Total	39.67	41.15	30			

*Significant values (p<0.05) – Analysis of variance test (ANOVA)
Subtitle: PPS = Pitch Pattern Sequence; GNMT = Group with no music training; GWMT = Group with music training; N = number of subjects

(naming) and nonverbal (humming) tasks. (Table 2). It was also possible to observe that both groups presented better performance in the PPS with nonverbal response, with worse performance of both groups in the PPS with verbal response. Nevertheless, GWMT presented superior performance when compared to GNMT (Table 3). The Chi-square test indicated association between musical exposure and the percentage of correct answers (Table 3).

According to ANOVA multivariate analysis, the mean results of the tests applied in the GNMT and GWMT groups,

Table 3. Performance of the participants in the temporal ordering test, considering the percentage of correct answers and the groups

Groups	Percentage of correct answers				Total	p Value
	0%	10% to 60%	70% to 90%	100%		
NVPPS GWMT	4	0	0	26	30	0.002*
NVPPS GNMT	9	7	1	13	30	
VPPS GWMT	14	3	9	4	30	
VPPS GNMT	22	5	3	0	30	

*Significant values (p<0.05) – Chi-square test

Subtitle: VPPS GNMT = Verbal Pitch Pattern Sequence of the group with no music training; NVPPS GWMT= Nonverbal Pitch Pattern Sequence of the group with music training

depending on the musical learning time, showed a significant difference between the groups only in the NVSM test (p = 0.011), demonstrating that the participants with more time of musical learning had better performance. In the verbal PPS it was possible to observe a tendency of difference between the groups, but with non-significant value (p=0.055).

DISCUSSION

It is known that, in the early years of life, the children show an efficient performance in detecting and locating sounds, in identifying complex sounds, such as the mother's voice, and in the melodic and rhythmic discrimination of simple musical segments, being the other comprehension and recognition skills developed in the course of time[16]. In the present study, all participants obtained the expected performance in the sound localization test, according to the same standards indicated in the literature for the 5 and 6 (years old) age groups, with no difference between gender, age range and group, probably due to the fact that sound localization and detection skills are primary and early in the development of the individual's auditory behavior[2].

Researchers who evaluated the listening skills of 4 to 5-year-old preschoolers also found adequate and similar performance in the sound localization test among the subjects, considering gender and age group[11,13,17]. However, another study with preschoolers aged from 4 to 5 years showed better male performance in the sound localization test, but without significant differences[18].

Auditory behavior is modified and improved with advancing age and with the number of auditory experiences gained throughout life and the musical practice is an "enhancer" agent of such skills[16]. Thus, the comparison between the exposure to music training and the performance in the NVSM and VSM tests showed that most of the 5 to 6-year-old children from GWMT performed better when compared to the children from GNMT, with the value of reference. The GNMT not only showed lower performance, but often below the reference values[2].

Music training seems to accelerate the development of these listening skills, since the association between performance on the VSM and NVSM tests and the age and group variables showed that 6-year-old children had better performance when compared to the children of the same age group with no music training. Besides, the 5-year-old children from the GWMT got right two sequences of four instruments (Figure 2), reaching the reference standard expected from the age of 6, when the addition of one more instrument in the sequence is indicated[2]. Response maturation and performance improvement with increasing age were evidenced in another study, which sought to investigate the correlation between simple temporal ordering and sound localization with environmental factors and language development of children from 4 to 5 years and 11 months, noting that the 5-year-old children were better than 4-year-old ones[18]. Other studies pointed out that 5-year-old children with musical experience performed better than children without musical experience by getting more sequences in the VSM test and mainly in the NVSM one[11,13], in which they noticed similar performance of these 5-year-old children and 6-year-old ones with no musical experience.

Temporal auditory processing consists in the perception of two or more sounds in a certain sequence of occurrence, within a certain time[6]. Many studies in the literature used the Pitch Pattern Sequence (PPS) to assess temporal ordering and the sound pattern discrimination in children aged from 7 to 12 years and adults, being scarce the studies that showed its application in children under 7 years old.[6, 19-23].

When analyzing the temporal ordering of frequency skill, it was found that the participants of the GWMT presented superior performance when compared to the GNMT, by humming (nonverbal PPS) and also by naming (verbal PPS) the sound patterns in the sequence correctly. A study that compared the performance of adult violinists with non musicians, in the frequency discrimination test, found that violinists had a higher performance on the test, agreeing with the findings of this study[24].

Besides, it was possible to observe that, during the nonverbal PPS, the GWMT participants reproduced the frequency of the test sound stimulus with a very close tone to the model offered. This evidence may be justified by the fact that musical practice enables a refinement of the perception and discrimination of the frequencies, even during the process of child development. These findings agree with studies that compared the performance of tuned singers with out-of-tune ones in the frequency discrimination test, noting that tuned singers and violinists had higher performance on the test[25].

However, although there was a significant difference in the performance between the groups with and without training, it was difficult to perform the PPS, with verbal response in the 5 and 6 age ranges, in both groups. Most participants in both groups did not reach the reference score for the PPS naming task test (verbal)[15]. Such difficulty may be related to the immaturity of the auditory cortex, since the age range evaluated in this study was lower than the lowest reference age group[15]. The complexity of the PPS with verbal response should also be taken into account. The request for verbal response in the PPS, in which the subject must name the three sound patterns emitted, following the sequence, requires the interhemispheric integration of the stimuli through the corpus callosum. This

cerebral commissure allows the right hemisphere functions, such as prosody, which promotes an affective tone to the speech and musical perception, to be interrelated with the left hemisphere functions, including speech. The request of the nonverbal response compared to the verbal one becomes an easier task because it requires less working memory and less elaborate cognitive processes[16].

One study analyzed the auditory processing of students aged from 9 to 14 years who failed in the simplified auditory processing assessment and, when comparing these findings with the results of the PPS, it was found that, among the tests applied, the students had greater difficulty and worse performance on the PPS[26]. This difficulty in performing the PPS was also found in another study, which aimed to determine the performance profile of children from 7 to 11 years and 5 months, with normal hearing, in the tasks of detection and identification of temporal order and sequence in free field.[20].

Observing the association between the verbal and nonverbal PPS performance and the time of exposure to the music training, it can be inferred that the musical experience favored the performance. It was verified that the 5 and 6-year-old children of this research, with music training, presented a similar performance to the 7-year-old children in the nonverbal PPS in achieving performance within the reference standard for this age. Although most participants in both groups failed to achieve the expected performance on the verbal PPS, it was possible to observe that the children with music training maintained their performance better than the children without music training. Out of a total of 30 participants, 10 scored from 80% to 100% and the others reached values close to these ones (Table 3). This may explain the tendency of association between exposure time to music training and the groups, with a value of p=0.055. It is likely that it could not be possible to observe this tendency of association due to the sample size, which is a limitation aspect of the study.

Other studies showed that musical training assisted in the development of the listening skills of sequential memory of verbal and nonverbal sounds, the phonological awareness and reading, as well as the overall development of the preschooler[12,13]. Therefore, it can be said that music is a great ally in the development of listening skills and in the school performance.

Given the findings of the present study, it was observed that musical practice is associated with better performance of auditory development of sequential memory and temporal ordering of the preschoolers in the sample early exposed to musical training. This finding may encourage further research to verify the impact of music practice on listening skills and discuss policies to encourage such practice of music learning in the school environment, as a strategy for global child development, among other objectives.

Besides, further research is needed to establish norms and standardize the applicability of PPS in younger children, especially those from 5 to 6 years old, who are in a period prior to the literacy process. The present study indicated favorable murmur responses, even at 5 years of age.

It is important to note that this study had limitations, as it is a convenience, non-probabilistic sample with a small number of participants in relation to the target population, which diminishes the generalization power of the findings. In this context, it is concluded that further research is needed to obtain more powerful results that prove the effects that musical practice can have on the development of preschoolers' listening skills and may reflect positively on their performance in the educational environment.

CONCLUSION

There was a significant difference in the temporal ordering skills of 5 to 6-year-old preschoolers, exposed or not to music learning. The 5 and 6-year-old preschoolers who participated in children's music learning performed better on tests that evaluated nonverbal and verbal sequential memory and the temporal ordering skills, when compared to preschoolers who were not exposed to music learning.

REFERENCES

1. Teixeira C, Griz S, Advíncula K, Caldas S. Tratado de Audiologia. 2nd ed. Rio de Janeiro: Guanabara Koogan; 2015. Chapter 2, Sistema Auditivo Central; p. 9-14.
2. Pereira L, Schochat E. Processamento Auditivo Central: manual de avaliação. São Paulo: Lovise; 1997.
3. Ramos BD. Audição fetal e neonatal: *prenataland neonatal hearing.* J Pediatr. 1994;70(3):137. http://dx.doi.org/10.2223/JPED.768.
4. Granier-Deferre C, Bassereau S, Ribeiro A, Jacquet AY, DeCasper AJ. A melodic contour repeatedly experienced by human near-term fetuses elicits a profound cardiac reaction one month after birth. Plos One. Feb;2011;6(2):1-10.
5. Shinn JB. Temporal processing: the basics. Hear J. 2002 Jul;56(7):52. http://dx.doi.org/10.1097/01.HJ.0000292557.52409.67.
6. Musiek EF. Frequency (Pitch) and Duration Pattern Tests. J Am Acad Audiol. 1994 July;5(4):265-68.
7. Gardner H. Estruturas da mente: a teoria das inteligências múltiplas. Porto Alegre: Artes Médicas Sul; 1994. 340 p.
8. Boéchat EM. Sistema Auditivo Nervoso Central/Plasticidade eDesenvolvimento. In: Boéchat EM, Menezes PL, Couto CM, Frizzo ACF, Scharlach RC, Anastasio ARC. Tratado de Audiologia. 2nd ed. Rio de Janeiro: Guanabara Koogan; 2015. p. 15-20.
9. Skoe E, Kraus N. A little goes a long way: how the adult brain is shaped by musical training in childhood. J Neurosci. 2012 Ago 22;32(34):11507-10. http://dx.doi.org/10.1523/JNEUROSCI.1949-12.2012. PMid:22915097.
10. Ohnishi T, Matsuda H, Asada T, Aruga M, Hirakata M, Nishikawa M, Katoh A, Imabayashi E. Functional Anatomy of Musical Perception in Musician. Cerebral Cortex. 2001 Ago;11(8):754-760.
11. Mendonça JE, Lemos MA. Relações entre prática musical, processamento auditivo e apreciação musical em crianças de cinco anos. Revista ABEM. 2010 Mar;18(23):58-66.
12. Eugênio ML, Escalda J, Lemos SMA. Desenvolvimento cognitivo, auditivo e linguístico em crianças expostas à música: produção de conhecimento nacional e internacional. Rev CEFAC. 2012 Set-Out;14(5):992-1003. http://dx.doi.org/10.1590/S1516-18462012005000038.
13. Escalda J, Lemos SMA, França CC. Habilidades de processamento auditivo e consciência fonológica em crianças de cinco anos com e sem experiência musical. J. Soc. Bras. Fonoaudiol. 2011 Jul-Set;23(3):258-263.

14. Toscano RDGP, Anastasio ART. Habilidades auditivas e medidas da imitância acústica em crianças de 4 a 6 anos de idade. Rev. CEFAC. 2012 Jul-Ago;14(4):650-8.

15. Otacílio LF, Campiotto AR, Levy C. Novo Tratado de fonoaudiologia. 3. ed. Barueri, São Paulo: Manole; 2013.

16. Lent R. Cem bilhões de Neurônios. São Paulo: Artmed; 2003.

17. Granzotti RBG, Layna SS, Carla PHARC, Kelly S, Domenis DR, Dornelas R, et al. Desenvolvimento neuropsicomotor e das habilidades auditivas em pré-escolares. J Hum Growth Dev. 2018;28(1):35-41.

18. Souza MA, Passaglio NJS, Souza VC, Scope RR, Lemos SMA. Ordenação temporal simples e localização sonora: associação com fatores ambientais e desenvolvimento de linguagem. Audiol Commun Res. 2015;20(1):24-31. http://dx.doi.org/10.1590/S2317-64312015000100001443.

19. Santos TS, Mancini PC, Sancio LP, Castro AR, Labanca L, Resende LM. Achados da avaliação comportamental e eletrofisiológica do processamento auditivo. Audiol. Commun. 2015 Jul-Set;20(3):225-32.

20. Frederigue-Lopes NB, Bevilacqua MC, Sameshima K, Costa OA. Desempenho de crianças normais em testes temporais auditivos em campo livre. Pró-Fono R. Atual. Cient. 2010 Abr-Jun;22(2):83-8. http://dx.doi.org/10.1590/S0104-56872010000200003.

21. Terto SSM, Lemos SMA. Aspectos temporais auditivos em adolescentes do 6º ano do ensino fundamental. Rev. CEFAC. 2013 Mar-Abr;15(2):271-86. http://dx.doi.org/10.1590/S1516-18462012005000040.

22. Duarte M, Gresele ADP, Pinheiro MMC. Processamento temporal em adultos pós-linguais usuários de implante coclear. Braz J Otorhinolaryngol. 2016 Mar-May;82(3):304-09.

23. Campos PD, Alvarenga KF, Frederigue NB, Nascimento LT, Sameshima K, Filho OAC, et al. Habilidades de ordenação temporal em usuários de implante coclear multicanal. Rev Bras Otorrinolaringol. 2008 Nov-Dez;74(6):884-9. http://dx.doi.org/10.1590/S0034-72992008000600011.

24. Nascimento FM, Monteiro RAM, Soares CD, Ferreira MIDC. Temporal sequencing abilities in musicians violinists and non-musicians. Int Arch Otorhinolaryngol. 2010 Abr-Jun;14(2):217-24. PMid:25992094.

25. Ishii C, Arashiro PM, Pereira LD. Ordenação e resolução temporal em cantores profissionais e amadores afinados e desafinados. Pró-Fono R. Atual. Cient. 2006 Set-Dez;18(3):285-92. http://dx.doi.org/10.1590/S0104-56872006000300008.

26. Vargas GC, Ferreira MIDC, Vidor DCGM, Machado MS. Avaliação simplificada e comportamental do processamento auditivo em escolares: estabelecendo relações. Rev CEFAC. 2014 Jul-Ago;16(4):1069-77. http://dx.doi.org/10.1590/1982-021620142413.